Greymouth Petroleum Limited
Kaimiro-A Hydraulic Fracturing Monitoring Programme Report 2015-2016

Technical Report 2016-113

Taranaki Regional Council
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Executive summary

Greymouth Petroleum Limited (GPL) operate the Kaimiro-A wellsite, located at 1180 Upland Road, Inglewood. The wellsite lies within the Waiongana catchment and contains two hydrocarbon producing wells and associated infrastructure.

GPL held resource consent 9413-1, authorising the discharge of contaminants associated with hydraulic fracturing activities into land at depths greater than 3,140 m TVDss beneath the Kaimiro-A wellsite until 1 June 2015. The consent was issued by Taranaki Regional Council (the Council) on 25 February 2013 and contained 16 special conditions which set out the requirements that GPL must satisfy. Consent 9413-1 was replaced by consent 10308-1 during the period under review (29 June 2016).

The following report for the period May 2015 to June 2016 outlines and discusses the results of the monitoring programme implemented by the Council in relation to the programme of hydraulic fracturing undertaken by GPL, within their Kaimiro-A wellsite. The report also assesses GPL's level of environmental performance and compliance with the resource consent held in relation to the activity.

During the monitoring period, Greymouth Petroleum Limited demonstrated an overall high level of environmental performance.

The programme of hydraulic fracturing undertaken by GPL at the Kaimiro-A wellsite during the period being reported was that of the Kaimiro-1 well which took place on 9 June 2015.

The programme of monitoring implemented by the Council in relation to previous hydraulic fracturing activities at the Kaimiro-A wellsite commenced in the 2013-2014 monitoring year. The results of monitoring undertaken between March 2014 and April 2015 were presented in the 2013-2015 biennial report (Taranaki Regional Council, 2015). The results of monitoring undertaken between May 2015 and June 2016 are presented in this report. Monitoring included groundwater sampling at one site, surface water biomonitoring at three sites and the analysis of samples for a range of chemical and isotopic analysis.

The results of the monitoring carried out by the Council indicates that the hydraulic fracturing activities undertaken by GPL have had no adverse effects on local groundwater resources or surface water quality. There were no Unauthorised Incidents recording non-compliance in respect of the resource consent, or provisions in regional plans, during the period under review.

GPL demonstrated a high level of environmental and good level of administrative performance and compliance with the resource consent over the reporting period.

For reference, in the 2015-2016 year, 71% of consent holders achieved a high level of environmental performance and compliance with their consents, while another 24% demonstrated a good level of environmental performance and compliance.

This report includes recommendations for the further monitoring of any hydraulic fracturing activities at the Kaimiro-A wellsite.

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1. Introduction

1.1 Compliance monitoring programme reports and the Resource Management Act 1991

1.1.1 Introduction

The following report outlines and discusses the results of the monitoring programme implemented by the Taranaki Regional Council (the Council) in relation to the programme of hydraulic fracturing undertaken by Greymouth Petroleum Limited (GPL) at their Kaimiro-A wellsite, 1180 Upland Road, Inglewood on 9 June 2015. The wellsite is located in the Waiongana catchment. The report also assesses GPL's level of environmental performance and compliance with the resource consent held in relation to the activity.

The programme of hydraulic fracturing undertaken by GPL at the Kaimiro-A wellsite during the 2014-2016 monitoring periods included the fracturing of one well; Kaimiro-1.

The programme of monitoring implemented by the Council in relation to this activity is a continuation of the monitoring carried out in relation to previous hydraulic fracturing activity at the wellsite during previous monitoring periods and included groundwater, surface water and discharge monitoring components.

A report was completed in July 2015 which outlined and discussed the results of the monitoring carried out during the 2013 to April 2015 monitoring periods. The current report provides an update on the results of further fracturing events that occurred at the site and further monitoring carried out since the initial report was written.

1.1.2 Structure of this report

Section 1 of this report is a background section. It sets out general information about compliance monitoring under the RMA and the Council's obligations and general approach to monitoring sites though annual programmes, the resource consent held by GPL in the Waiongana catchment, the nature of the monitoring programme in place for the period under review, and a description of the activities and operations conducted in the Company's site/catchment.

Section 2 presents the results of monitoring during the period under review, including scientific and technical data.

Section 3 discusses the results, their interpretations, and their significance for the environment.

Section 4 presents recommendations for further monitoring at the site.

A glossary of common abbreviations and scientific terms, and a bibliography, are presented at the end of the report.

1.1.3 The Resource Management Act 1991 and monitoring

The RMA primarily addresses environmental 'effects' which are defined as positive or adverse, temporary or permanent, past, present or future, or cumulative. Effects may arise in relation to:

(a) the neighbourhood or the wider community around an activity, and may include cultural and social-economic effects;
(b) physical effects on the locality, including landscape, amenity and visual effects;
(c) ecosystems, including effects on plants, animals, or habitats, whether aquatic or terrestrial;
(d) natural and physical resources having special significance (for example recreational, cultural, or aesthetic);
(e) risks to the neighbourhood or environment.

In drafting and reviewing conditions on discharge permits, and in implementing monitoring programmes, the Council is recognising the comprehensive meaning of 'effects' inasmuch as is appropriate for each activity. Monitoring programmes are not only based on existing permit conditions, but also on the obligations of the RMA to assess the effects of the exercise of consents. In accordance with section 35 of the RMA, the Council undertakes compliance monitoring for consents and rules in regional plans, and maintains an overview of the performance of resource users and consent holders. Compliance monitoring, including both activity and impact monitoring, enables the Council to continually re-evaluate its approach and that of consent holders to resource management and, ultimately, through the refinement of methods and considered responsible resource utilisation, to move closer to achieving sustainable development of the region's resources.

1.1.4 Evaluation of environmental and administrative performance

Besides discussing the various details of the performance and extent of compliance by the consent holder/s during the period under review, this report also assigns a rating as to each Company's environmental and administrative performance.

Environmental performance is concerned with actual or likely effects on the receiving environment from the activities during the monitoring year. **Administrative performance** is concerned with the Company's approach to demonstrating consent compliance in site operations and management including the timely provision of information to Council (such as contingency plans and water take data) in accordance with consent conditions.

Events that were beyond the control of the consent holder and unforeseeable (that is a defence under the provisions of the RMA can be established) may be excluded with regard to the performance rating applied. For example loss of data due to a flood destroying deployed field equipment.

The categories used by the Council for this monitoring period, and their interpretation, are as follows:

Environmental Performance

- **High:** No or inconsequential (short-term duration, less than minor in severity) breaches of consent or regional plan parameters resulting from the activity; no adverse effects of significance noted or likely in the receiving environment .The Council did not record any verified unauthorised incidents involving significant environmental impacts and was not obliged to issue any abatement notices or infringement notices in relation to such impacts.

- **Good:** Likely or actual adverse effects of activities on the receiving environment were negligible or minor at most. There were some such issues noted during monitoring, from self reports, or in response to unauthorised incident reports, but these items were not critical, and follow-up inspections showed they have been dealt with. These minor issues were resolved positively, co-operatively, and quickly. The Council was not obliged to issue any abatement notices or infringement notices in relation to the minor non-compliant effects; however abatement notices may have been issued to mitigate an identified potential for an environmental effect to occur.

  For example:

  - High suspended solid values recorded in discharge samples, however the discharge was to land or to receiving waters that were in high flow at the time;
  - Strong odour beyond boundary but no residential properties or other recipient nearby.

- **Improvement required:** Likely or actual adverse effects of activities on the receiving environment were more than minor, but not substantial. There were some issues noted during monitoring, from self reports, or in response to unauthorised incident reports. Cumulative adverse effects of a persistent minor non-compliant activity could elevate a minor issue to this level. Abatement notices and infringement notices may have been issued in respect of effects.

- **Poor:** Likely or actual adverse effects of activities on the receiving environment were significant. There were some items noted during monitoring, from self reports, or in response to unauthorised incident reports. Cumulative adverse effects of a persistent moderate non-compliant activity could elevate an 'improvement required' issue to this level. Typically there were grounds for either a prosecution or an infringement notice in respect of effects.

Administrative performance

- **High:** The administrative requirements of the resource consents were met, or any failure to do this had trivial consequences and were addressed promptly and co-operatively.

- **Good:** Perhaps some administrative requirements of the resource consents were not met at a particular time; however this was addressed without repeated interventions from the Council staff. Alternatively adequate reason was provided for matters such as the no or late provision of information, interpretation of 'best practical option' for avoiding potential effects, etc.

- **Improvement required:** Repeated interventions to meet the administrative requirements of the resource consents were made by Council staff. These matters took some time to resolve, or remained unresolved at the end of the period under review. The Council may have issued an abatement notice to attain compliance.

- **Poor**: Material failings to meet the administrative requirements of the resource consents. Significant intervention by the Council was required. Typically there were grounds for an infringement notice.

In reference, in the 2015-2016 year, 71% of consent holders in Taranaki monitored through tailored compliance monitoring programmes achieved a high level of environmental performance and compliance with their consents, while another 24% demonstrated a good level of environmental performance and compliance with their consents

1.2 Process description

1.2.1 Hydraulic fracturing

Hydraulic fracturing is a reservoir stimulation technique used to increase the flow of hydrocarbons to the surface. The primary objective of hydraulic fracturing is to increase the permeability of the target reservoir by creating numerous small, interconnected fractures, thus increasing the flow of hydrocarbons from the formation to a given well. The process of hydraulic fracturing has enabled companies to produce hydrocarbons at economically viable rates from extremely low permeability reservoirs and those that have become depleted using conventional production techniques.

The process of hydraulic fracturing involves the pumping of fluids and a proppant (medium-grained sand or small ceramic pellets) down a well, through a perforated section of the well casing, and into the target reservoir. The fluid mixture is pumped at a pressure that exceeds the fracture strength of the reservoir rock in order to create fractures. Once fractures have been initiated, pumping continues in order to force the fluid and proppant into the fractures created. The proppant is designed to keep the fractures open when the pumping is stopped. The placement of proppant into the fractures can be assisted by the use of cross-linked gels (gel fracturing) or turbulent flow (slick-water fracturing).

Gel fracturing

Gel fracturing utilises cross-linked gel solutions, which are liquid at the surface but, when mixed, form long-chain polymer bonds and thus become viscous gels. These gels are used to transport the proppant into the formation. Once in the formation they 'break' back with time, temperature and the aid of gel breaking chemicals into a liquid state and are flowed back to surface, without disturbing the proppant which remains in place and enhances the flow of hydrocarbons back to the surface.

Slick water fracturing

Slick water fracturing utilises water based fracturing fluids with friction-reducing additives. The addition of the friction reducers allows the fracturing fluids and proppant to be pumped to the target zone at higher rates and reduced pressures, than when using water alone. The higher rate creates turbulence within the fluid column holding the proppant and enabling its placement into the open fractures and enhancing the flow of hydrocarbons back to the surface. [1]

Nitrogen gas assisted fracturing

Nitrogen gas assisted fracturing involves replacing some of the fluid used in the fracturing process with nitrogen gas, which can fracture rock at high pressures much like water. While nitrogen (N^2) is a gas at room temperature, it can be maintained in a liquid state through cooling and pressurisation. Nitrogen assisted fracking is extremely beneficial from a production standpoint as inevitably during the fracturing process some of the water pumped down the well remains underground in the rock formation, which can block some of the small pores inhibiting hydrocarbon recovery. Nitrogen gas achieves the same purpose as water but returns more easily to the surface. [2] More indirectly, a reduction in the volume of water used also reduces the total concentration of chemical additives required and the volume of water returning to the surface that requires subsequent disposal. [2]

1.2.2 Kaimiro-A wellsite history

The Kaimiro-A wellsite has been in operation since 1982. The land on which the wellsite is located has historically been used for dairy farming. The area around the wellsite and is rural with low population density. The closest residential communities are Egmont Village, a small rural community which lies approximately 2.2 km to the north of the site and Inglewood, a rural town which lies approximately 3.6 km east of the wellsite. The site is located in an active petroleum exploration area. GPL's petroleum exploration activity dominates this area with Todd and TAG oil fields located north-east and south-east from the wellsite.

The Kaimiro-2ST1 well was sidetracked from the original Kaimiro-2 well between September 2010 and January 2011. It was later worked over between February and March 2014. Hydraulic fracturing took place on 29 April 2014. Kaimiro-1 was drilled from the 8th of July 1982 to 27th of October 1982, reaching a total depth of 4,999 m MD. The well was cased with 7" 32 lbs/ft N-80 from 4,991 m to surface, and is currently completed with as a 3 1/2" 9.2 lbs/ft L80 production tubing. One stimulation job was performed in the well over one interval into perforations; the hydraulic fracturing treatment was placed on 9 June 2015.

An outline of all hydraulic fracturing activities carried out by GPL at the Kaimiro-A wellsite is provided below in Table 1.

The location of the wellsite is illustrated in Figure 1.

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1 *http://geology.com/energy/hydraulic-fracturing-fluids/*

2 *http://frackwire.com/nitrogen-gas-fracking*

Table 1 Summary of hydraulic fracturing activity (2014-2016)

Well	Wellsite	Consent	Date	Injection zone (m TVDss)	Formation
Kaimiro-2ST1	Kaimiro-A	9413-1	29/04/2014	3,328 to 3,331	McKee
				3,790 to 3,793.1	
				3,799 to 3,802.1	
Kaimiro-1			9/06/2015	3,603 to 3,612	McKee

A report was completed in July 2015 (Taranaki Regional Council, 2015) which outlined and discussed the results of the monitoring carried out during the 2013-2015 monitoring periods in relation to the fracturing of the Kaimiro-2ST1 well in April 2014. The following report provides an update on the monitoring carried out in relation to the fracturing of the Kaimiro-1 well in June 2015.

1.3 Resource consent

1.3.1 Discharges onto and into land

Section 15(1) (b) of the RMA stipulates that no person may discharge any contaminant onto or into land, which may result in that contaminant (or any other contaminant emanating as a result of natural processes from that contaminant) entering water, unless the activity is expressly allowed for by a resource consent, a rule in a regional plan, or by national regulations.

GPL held resource consent **9413-1**, authorising the discharge of contaminants into land at the Kaimiro-A wellsite. The consent was issued by the Council on 25 February 2013, under Section 87(e) of the RMA and replaced by consent **10308-1** on 29 June 2016. Consent 9413-1 is the consent under which Kaimiro-2ST1 and Kaimiro-1 were fractured. The consent contained 16 special conditions which set out the requirements that GPL must satisfy, as summarised below:

- Condition 1 stipulates the minimum depth below which the injection of hydraulic fracturing fluids must occur.
- Condition 2 stipulates the date after which no hydraulic fracturing fluids shall be discharged into the reservoir.
- Condition 3 requires the consent holder to ensure that the exercising of the consent does not result in any contaminants reaching any useable freshwater (ground or surface water).
- Conditions 4, 5, 6 and 7 relate to fresh water monitoring requirements, to allow compliance with condition 3 to be assessed.
- Condition 8 requires the consent holder to carry out pressure testing of equipment prior to discharging.
- Condition 9 requires the consent holder to submit a pre-fracturing discharge report prior to any discharge occurring.
- Condition 10 is a notification requirement.
- Condition 11 requires the consent holder to submit a post-fracturing discharge report after the completion of the hydraulic fracturing programme for each well.
- Condition 12 stipulates how the reports required by conditions 9 and 11 are to be submitted.

- Condition 13 requires the consent holder to allow the Council access to a location where samples of hydraulic fracturing and return fluids can be obtained.
- Condition 14 requires the consent holder to use best practicable options.
- Condition 15 relates to the composition of the fracturing fluid.
- Consent 16 is a review provision.

A copy of the consent is included in Appendix I.

Figure 1 Location of Kaimiro-A wellsite where hydraulic fracturing occurred during the period under review

1.4 Monitoring programme

1.4.1 Introduction

Section 35 of the RMA sets out obligations upon the Council to gather information, monitor, and conduct research on the exercise of resource consents, and the effects arising, within the Taranaki region and report upon these.

The Council may therefore make and record measurements of physical and chemical parameters, take samples for analysis, carry out surveys and inspections, conduct investigations, and seek information from consent holders.

The monitoring programme implemented in relation to the hydraulic fracturing of the Kaimiro-1 well consisted of four primary components.

1.4.2 Programme liaison and management

There is generally a significant investment of time and resources by the Council in:

- ongoing liaison with resource consent holders over consent conditions and their interpretation and application;
- in discussion over monitoring requirements;
- preparation for any reviews;
- renewals;
- new consents;
- advice on the Council's environmental management strategies and content of regional plans; and
- consultation on associated matters.

1.4.3 Review of consent holder submitted data

As required by the conditions of consent 9413-1, GPL submitted pre and post-fracturing discharge reports to the Council for the well fractured during the period under review. Pre-fracturing discharge reports provide an outline of the proposed fracturing operations in relation to the well, while post-fracturing reports confirm details of what actually occurred. The specific range of information required in each report is stipulated in the conditions of the resource consent.

1.4.4 Chemical sampling

The primary component of the monitoring programme implemented by the Council was the sampling of a groundwater monitoring well in the vicinity of the Kaimiro-A wellsite, and the analysis of the results.

In the absence of any suitable existing sampling sites, condition 5 of consent 9413-1 required GPL to install a suitable monitoring bore for the purposes of obtaining groundwater samples. The design and location of the monitoring bore was discussed and agreed with Council staff prior to installation.

The details of the monitoring bore installed are included in Table 2 and its proximity to the wellsite is illustrated in Figure 2.

Table 2 Details of groundwater sites included in the monitoring programme

Hydraulically fractured well	Monitoring site	Distance from wellsite location (m)	Total depth (m)	Screened interval (m BGL)	Aquifer
Kaimiro-1	GND2447	31	37	25 - 37	Volcanics

Samples of groundwater were obtained before fracturing to provide a baseline reference of groundwater composition, with a further round of sampling carried out three months and one year post-fracturing for comparison with baseline results.

All samples were transported to Hill Laboratories Limited for analysis following standard chain of custody procedures.

In addition to the sampling of local groundwater, samples of both the hydraulic fracturing fluid and the reservoir fluids produced back to the wellhead immediately following each fracturing event (return fluids) were obtained for analysis at Hill Laboratories Limited.

1.4.5 Biomonitoring surveys

Biomonitoring surveys are carried out to assess whether any stormwater discharges from the Kaimiro-A wellsite during the course of fracturing operations had resulted in any detrimental effects upon the biological communities within the receiving waters.

Biological surveys were performed pre and post-fracturing in the vicinity of the wellsite. Surveys were carried out in two unnamed tributaries of the Mangaoraka Stream, as these are the nearest surface water bodies to the stormwater discharge locations of the Kaimiro-A wellsite.

It should be noted that the sampling sites are also downstream of farm effluent ponds.

The details of each biomonitoring site included in the survey are presented in Table 3 and their proximity to the wellsite is illustrated in Figure2.

Table 3 Details of biomonitoring sites included in the monitoring programme

Site	Site code	GPS reference (NZTM)	Location
1	MRK 000198	E1700117 N5664652	Major tributary approx. 50 m u/s of confluence with minor tributary
2	MRK 000204	E1700054 N5664636	Minor tributary (receives discharge) 150 m d/s of Upland Road
3	MRK 000207	E1700171 N5665679	Major tributary approx. 50 m d/s of confluence with minor tributary

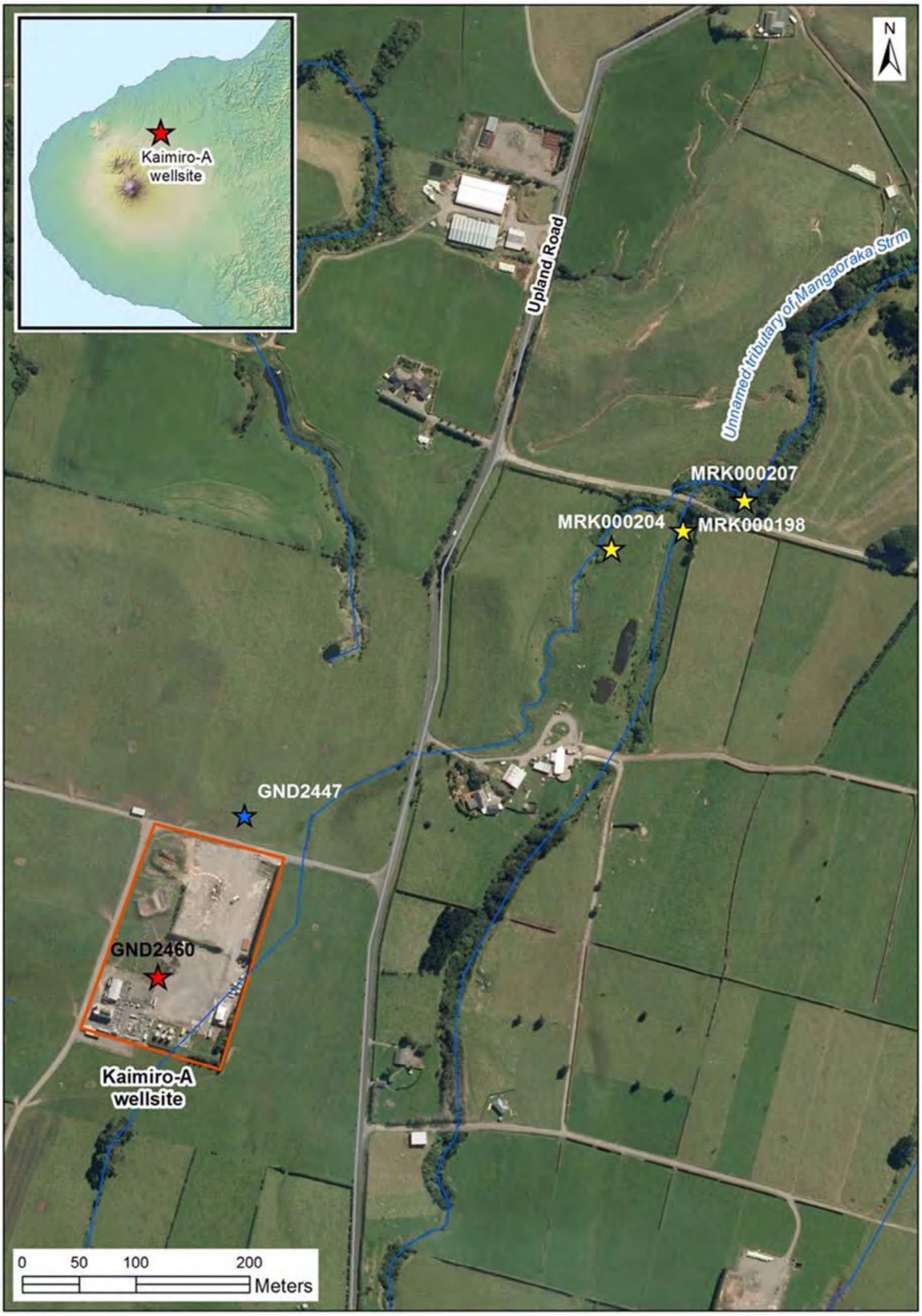

Figure 2 Location of groundwater (blue star) and surface water sampling sites (yellow stars) in relation to the Kaimiro-1 well (red star)

2. Results

2.1 Consent holder submitted data

2.1.1 Kaimiro-1 post-fracturing discharge report

The conclusions from the Kaimiro-1 post-fracturing discharge report are summarised as follows:

- One discrete zone was hydraulically fractured on 9 June 2015, at depths between 3,603 and 3,612 m TVDss.
- A total of 1,440 barrels (bbls) (229 m^3) of liquid was discharged into the fractured zone. The total proppant weight was 47 tonnes.
- By mass, 81.1% of the fluid injected was water, 16.9% was proppant and 2.0% was chemicals.
- Pressure testing of the tubing and well head equipment was carried out prior to fracturing commencing. The maximum pressure exerted during the fracturing programme remained below the successfully tested levels at all times.
- The Kaimiro-1 well was opened for flowback immediately after placement of the proppant. Due to the fact that the flowback fluid from hydraulic fracturing operations consists of a mixture of the original fluid with native reservoir fluids, it is not feasible to calculate the exact quantity remaining underground. However, it is clear from the composition and physical properties of the flowback fluid that it is dominantly hydraulic fracturing fluid during the initial stages of flowback, and from this a reasonable estimate of fluid remaining underground can be made. At the completion of all flow-back operations, approximately 2,187 bbls (348 m^3) of fracture fluids and formation fluid were returned to the surface, leaving no fracture fluid underground. It is estimated that all of the proppant injected (47 tonnes) remains in the formation, with small volumes expected to have settled inside the casing, where they may remain, unless circulated to the surface during later well interventions.
- All fluids that returned to the surface during flowback of each hydraulic fracturing operation were disposed of by deep well injection at the Kaimiro-G wellsite as authorised by consent 9470-1.
- It is considered that the mitigation measures implemented by GPL were effective in ensuring there were no adverse environmental effects associated with fracturing operations.

2.2 Chemical sampling

2.2.1 Kaimiro-1 groundwater sampling survey

One site, GND2447, was sampled to monitor the effects of the hydraulic fracturing of the Kaimiro-1 well on local groundwater resources. This is the same well that was sampled for the monitoring in relation to the hydraulic fracturing of the Kaimiro-2ST1 well.

The results of the monitoring carried out indicate that parameters have remained stable, with only slight fluctuations observed in electrical conductivity, chloride concentrations and pH. The changes in the concentrations of these analytes are a result of natural variations in water composition and are unrelated to fracturing activities.

Methane was detected in the well at concentrations similar to previous sampling rounds. Concentrations were generally low and within the expected ranges typically seen in shallow groundwater across Taranaki.

Certificates of analysis are included in Appendix II.

Table 4 Results of groundwater analysis at GND2447

Parameter	Unit	Range		GND2447				
		Minimum	Maximum					
Sample date	-	-	-	25 Mar 14	04 Aug 14	23 Apr 15	08 Sep 15	01 Jul 16
Sample time	-	-	-	11:47	10:45	12:20	10:10	11:45
Lab number	-	-	-	TRC149606	TRC1410739	TRC151704	TRC152879	TRC162758
Total alkalinity	g/m^3 $CaCO_3$	74	89	82	89	74	78	78
Barium	mg/kg	0.0129	0.023	0.0129	0.021	0.0176	0.022	0.023
Benzene	g/m^3	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Dissolved bromine	g/m^3	0.038	0.079	0.079	0.051	0.041	0.042	0.038
Calcium	g/m^3	9.7	13.8	9.7	13.8	10.1	10.6	10.5
Chloride	g/m^3	8.0	12.5	12.5	8.8	8.0	8.5	8.7
Conductivity	mS/m@20ºC	16.9	24.2	21.2	20.0	16.9	17.7	24.2
Dissolved copper	g/m^3	<0.0005	0.0086	0.0086	<0.0005	<0.0005	<0.0005	<0.0005
Ethylbenzene	g/m^3	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Ethane	g/m^3	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Ethylene	g/m^3	<0.003	<0.004	<0.003	<0.003	<0.004	<0.003	<0.004
Dissolved iron	g/m^3	0.19	10.6	0.19	5.1	7.7	9.4	10.6
Formaldehyde	g/m^3	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ethylene glycol	g/m^3	<4	<4	<4	<4	<4	<4	<4
Hydrocarbons	g/m^3	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7
Bicarbonate	g/m^3 HCO_3	91	109	100	109	91	95	95
Total hardness	g/m^3 $CaCO_3$	40	53	40	53	44	46	47
Dissolved mercury	g/m^3	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008
Potassium	g/m^3	5.9	8.5	8.5	5.9	6.1	7.2	6.9
Methanol	g/m^3	<2	<2	<2	<2	<2	<2	<2
Methane	g/m^3	3.5	5.7	3.7	3.6	5.7	5.4	3.5
Magnesium	g/m^3	3.9	5.0	3.9	4.6	4.6	4.8	5.0
Dissolved manganese	g/m^3	0.22	0.39	0.22	0.39	0.29	0.30	0.31
Sodium	g/m^3	16.4	21	21	16.6	16.4	17.7	18.5
Nickel	mg/kg	<0.0005	0.0009	0.0008	0.0009	<0.0005	<0.0005	<0.0005
Nitrate & nitrite nitrogen	g/m^3 N	0.004	0.007	0.007	<0.02	<0.2	0.005	0.004
Nitrite nitrogen	g/m^3 N	<0.002	0.006	<0.002	<0.02	<0.2	0.006	0.004

Parameter	Unit	Range		GND2447				
		Minimum	Maximum					
Sample date	-	-	-	25 Mar 14	04 Aug 14	23 Apr 15	08 Sep 15	01 Jul 16
Sample time	-	-	-	11:47	10:45	12:20	10:10	11:45
Lab number	-	-	-	TRC149606	TRC1410739	TRC151704	TRC152879	TRC162758
Nitrate nitrogen	g/m^3 N	<0.002	0.005	0.005	<0.02	<0.2	<0.002	<0.002
pH	pH	6.6	7.8	7.1	7.0	6.6	6.7	7.8
Propylene glycol	g/m^3	<4	<4	<4	<4	<4	<4	<4
Sulphate	g/m^3	5.6	5.6	5.6	<0.5	<0.5	<0.5	<0.5
Total dissolved solids	g/m^3	159	194	194	163	159	160	167
Toluene	g/m^3	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
o-Xylene	g/m^3	<0.0010	0.0013	0.0013	<0.0010	<0.0010	<0.0010	<0.0010
m-Xylene	g/m^3	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Dissolved zinc	g/m^3	0.004	0.0135	0.004	0.0135	0.0099	0.0058	0.0067

2.2.2 Carbon isotope analysis

Since 2014, four groundwater samples collected from GND2447 have been sent to GNS Science for carbon isotope analysis in their National Isotope Centre. The isotopic analysis is used to calculate a delta carbon13 (δ13C) value for a given sample, which is then used to determine the origin of the gas. Generally, a δ13C value that exceeds -50‰ indicates biogenic methane and a δ13C value less than -50‰ indicates thermogenic methane. The higher or lower the δ13C values, the stronger the isotopic signature. A δ13C value in the vicinity of -50‰ can indicate a mixture of both biogenic and thermogenic methane. Results of analyses undertaken in the period being reported are compared with previous results in Table 5 below.

Table 5 Results of carbon isotope analysis at GND2447

GND2447				
Sample date	4 Aug 2014	23 Apr 2015	8 Sep 2015	1 Jul 2016
δ13C Value	-89‰	-89‰	-88‰	-84.5‰

The results show that the methane gas present in GND2447 is strongly biogenic and that gas composition has remained consistently biogenic across the sampling record.

It is important to note that the results are issued from the analysing laboratory with an uncertainty of measurement of ±10‰.

2.2.3 Hydraulic fracturing and return fluids

The results of the analyses carried out on samples of the hydraulic fracturing fluid used in the treatment of the Kaimiro-1 well during the 9 June 2015 fracturing event is summarised below in Table 6. The certificates of analysis are included in Appendix III.

Due to the viscosity of the fluid samples obtained, the range of analyses that were able to be performed on each sample were limited, as samples taken were gel like in composition, as opposed to a liquid. While the fracturing fluid is predominantly comprised of water, specialised additives are used to increase the viscosity of the fluid in order to suspend the proppant prior to injection.

Due to the volume of water used in the fracturing fluid mixture, all additives included in the mixture are highly dilute.

Table 6 Results of hydraulic fracturing fluid sampling

Parameter	Unit	Kaimiro-1
Sample date	-	09 Jun 2015
Lab number	-	TRC152880
Benzene	g/m^3	<0.10
Ethylbenzene	g/m^3	0.018
Ethylene glycol	g/m^3	43
Total hydrocarbons	g/m^3	300
Propylene glycol	g/m^3	<4
Toluene	g/m^3	0.016
o-Xylene	g/m^3	<0.010
m-Xylene	g/m^3	<0.02

Composite samples of return fluid from Kaimiro-1 were submitted for analysis. Return fluids are comprised of a mixture of hydraulic fracturing fluids and formation fluids produced from the target reservoir, following the completion of the hydraulic fracturing process. The relative concentrations of each contributing fluid type change as the volume of fluid produced from the well increases. Immediately following the opening of the well post-fracturing, a high proportion of the fluid returning to the wellhead is that injected during the hydraulic fracturing process. As the volume of fluid produced from the well increases, the proportion of hydraulic fracturing fluid reduces in relation to formation fluids.

The results of the analyses carried out on the return fluid sample obtained following the hydraulic fracturing of the Kaimiro-1 well are summarised below in Table 7 and the certificates of analysis are included in Appendix III. The relatively high levels of salinity (sodium and chloride) in the samples indicate that the composite samples prepared contained a greater proportion of saline reservoir fluids than fluids introduced during fracturing activities. The presence of elevated levels of BTEX compounds are indicative of fluids being drawn from a hydrocarbon bearing reservoir.

Table 7 Results of return fluid sampling

Parameter	Unit	Kaimiro-1
Sample date	-	09-Jun-15
Lab number	-	TRC152881
Total alkalinity	g/m^3 $CaCO_3$	1,680
Barium	mg/kg	21
Benzene	g/m^3	1.71
Bromide	g/m^3	14.9
Calcium	g/m^3	79
Chloride	g/m^3	6,300
Conductivity	mS/m@20^{0}C	2,130
Dissolved copper	g/m^3	<0.005
Ethylbenzene	g/m^3	0.0178
Dissolved iron	g/m^3	11.1
Formaldehyde	g/m^3	0.25
Ethylene glycol	g/m^3	<20
Bicarbonate	g/m^3 HCO_3	181
Total hardness	g/m^3 $CaCO_3$	250
Potassium	g/m^3	530
Methanol	g/m^3	6
Magnesium	g/m^3	12
Dissolved manganese	g/m^3	3.4
Sodium	g/m^3	4,500
Nickel	mg/kg	<0.03
Nitrate & nitrite nitrogen	g/m^3 N	0.007
Nitrite	g/m^3 N	<0.002
Nitrate	g/m^3 N	0.007
pH	pH	6.8
Propylene glycol	g/m^3	<20
Dissolved sulphur	g/m^3	8
Sulphate	g/m^3	23
Toluene	g/m^3	0.44
o-Xylene	g/m^3	0.037
m-Xylene	g/m^3	0.064
Dissolved zinc	g/m^3	0.06

2.2.4 Biomonitoring survey

The Council's 'kick-sampling' technique was used at three sites to collect streambed macroinvertebrates from two unnamed tributaries of the Mangaoraka Stream in relation to the Kaimiro-A wellsite. The intention of these surveys was to determine the health of the macroinvertebrate communities prior to fracturing, which then allowed a comparison with the health of macroinvertebrate communities once fracturing had been completed. Samples were processed to provide number of taxa (richness), MCI and $SQMCI_S$ scores for each site.

The MCI is a measure of the overall sensitivity of the macroinvertebrate community to the effects of organic pollution in stony streams. It is based on the presence/absence of taxa with varying degrees of sensitivity to environmental conditions. The $SQMCI_S$ takes into account taxa abundances as well as sensitivity to pollution. It may indicate subtle changes in communities, and therefore be the more relevant index if non-organic impacts are occurring. Significant differences in either the MCI or the $SQMCI_S$ between sites indicate the degree of adverse effects (if any) of the discharges being monitored.

Site 2 had substantially lower macroinvertebrate indices than sites 1 and 3 which is consistent with results from past surveys. The reduced MCI values are a result of high iron oxide levels in the minor tributary of the Mangaoraka Stream having high iron oxide levels which causes lower habitat quality for macroinvertebrates. The major tributary of the Mangaoraka Stream which sites 1 and 3 are situated on does not have the same iron oxide issue. The macroinvertebrate indices at sites 1 and 3 were generally consistent with previous sampling results with only minor differences recorded between the two sites for taxa richness and MCI scores. Site 1 continued to show a higher than usual $SQMCI_S$ score which was largely due to the mayfly *Zephlebia* group being recorded as 'extremely abundant'. Overall, there was no evidence that hydraulic fracturing at the Kaimiro-A wellsite had any recent detrimental effects on the macroinvertebrate communities in either of the minor and main tributary of the Mangaoraka Stream.

A copy of the biomonitoring report is included in Appendix IV.

2.3 Investigations, interventions and incidents

The monitoring programme for the period under review was based on what was considered to be an appropriate level of monitoring, review of data, and liaison with the consent holder. During the period matters may arise which require additional activity by the Council, for example provision of advice and information, or investigation of potential or actual courses of non-compliance or failure to maintain good practices. A pro-active approach that in the first instance avoids issues occurring is favoured.

The Council operates and maintains a register of all complaints or reported and discovered excursions from acceptable limits and practices, including non-compliance with consents, which may damage the environment. The Incident Register includes events where the company concerned has itself notified the Council. The register contains details of any investigation and corrective action taken.

Complaints may be alleged to be associated with a particular site. If there is potentially an issue of legal liability, the Council must be able to prove by investigation that the identified company is indeed the source of the incident (or that the allegation cannot be proven).

On 5 October 2015, it was discovered that GPL were in breach of consent 9413-1 due to discharging hydraulic fracturing fluid after 1 June 2015. Special condition 2 of the consent states:

There shall be no discharge of hydraulic fracturing fluids into the reservoir after 1 June 2015.

A 14-day letter was sent to GPL on 6 October 2015 requesting an explanation for the breach. The Company stated the reason was that operations were programmed to occur before 1 June 2015, however due to various operational and logistical delays, pumping did not take place until 9 June 2015. The Council accepted this explanation and took no further action against GPL. The breach led to their administrative performance for the monitoring period being downgraded from 'high' to 'good' (See section 3.2). There are no adverse environmental effects associated with the breach. The consent was replaced on 29 June 2016 by consent 10308-1, which expires 1 June 2032.

3. Discussion

3.1 Environmental effects of hydraulic fracturing on useable freshwater resources

This is a report regarding on-going monitoring of hydraulic fracturing that occurred in the 2014-2016 period at the Kaimiro-A wellsite.

To assess the level of environmental performance and compliance by GPL during the period being reported, the monitoring programme implemented by the Council included a groundwater monitoring component. This included the sampling of groundwater at a site in the vicinity of the hydraulically fractured well. The groundwater system was surveyed prior to any hydraulic fracturing occurring to determine baseline conditions, allowing comparisons to be made with post-fracturing results.

The results of post-fracturing groundwater sampling carried out in the vicinity of the Kaimiro-A wellsite showed only very minor variations in water composition in comparison to baseline results. The minor variations in some analytes are a result of natural variations in water composition and unrelated to fracturing activities.

Methane was detected in the groundwater monitoring well. Concentrations were within the expected range for shallow groundwater in Taranaki. Carbon isotope analysis carried out indicates that the methane gas present in GND2447 is strongly biogenic in origin. No traces of substances associated with hydraulic fracturing fluids, or hydrocarbons relating to fracturing activities were present in the groundwater.

The result of the biomonitoring survey undertaken suggests that hydraulic fracturing operations did not result in adverse effects on local surface water resources, with community indices in line with reference sites of similar altitude.

In summary, the monitoring carried out by the Council to date indicates that the hydraulic fracturing activities undertaken by GPL at the Kaimiro-A wellsite have had no adverse effects on local groundwater or surface water resources.

3.2 Evaluation of Performance

A tabular summary of the consent holder's compliance record for the year under review is set out in Table 8.

Table 8 Summary of Company performance with regard to consent 9413-1 (1 July 2014-30 June 2016)

Purpose: *To discharge contaminants associated with hydraulic fracturing activities into land at depths greater than 3,140 mTVD beneath the Kaimiro-A wellsite.*		
Condition requirement	**Means of monitoring during period under review**	**Compliance achieved?**
1. Any discharge shall occur below 3,140 mTVD	Assessment of consent holder submitted data	Yes
2. No discharge of hydraulic fracturing fluids after 1 June 2015	Assessment of consent holder submitted data and site inspections	No

Purpose: *To discharge contaminants associated with hydraulic fracturing activities into land at depths greater than 3,140 mTVD beneath the Kaimiro-A wellsite.*		
Condition requirement	**Means of monitoring during period under review**	**Compliance achieved?**
3. Exercise of consent shall not result in any contaminants reaching any useable freshwater (groundwater or surface water)	Results of groundwater and surface water monitoring	Yes
4. Consent holder shall undertake sampling programme	Development and certification of a monitoring programme	Yes
5. A dedicated groundwater monitoring well will need to be installed	Development and certification of a monitoring programme	N/A
6. Sampling programme shall follow recognised field procedures and be analysed for a specified range of chemical parameters	Development and certification of a monitoring programme and assessment of results	Yes
7. All sampling to be carried out in accordance with a certified sampling and analysis plan	Development and certification of a sampling and analysis plan	Yes
8. Well and equipment pressure testing to be carried out prior to any hydraulic fracturing programme commencing	Assessment of consent holder submitted data	Yes
9. A pre-fracturing discharge report is to be provided to the Council 14 days prior to discharge	Pre-fracturing discharge report received	Yes
10. Consent holder shall notify the Council of hydraulic fracturing discharge	Notification received	Yes
11. A post-fracturing discharge report is to be provided to the Council within 60 days after the hydraulic fracturing programme is completed	Post-fracturing discharge report received	Yes
12. The reports outlined in conditions 9 and 11 must be emailed to consents@trc.govt.nz	Reports received via email	Yes
13. The consent holder shall provide access to a location where samples of hydraulic fracturing fluids and return fluids can be obtained by the Council officers	Access provided	Yes
14. Consent holder to adopt best practicable option at all times	Site inspections, sampling and assessment of consent holder submitted data	Yes
15. No hydrocarbon based hydraulic fracturing fluid shall be discharged	Assessment of consent holder submitted data and sampling of fracturing fluid	Yes
16. Notice of Council to review consent	No provision for review during period	N/A
Overall assessment of environmental performance and compliance in respect of this consent		**High**
Overall assessment of administrative performance and compliance in respect of this consent		**Good**

* Hydraulic fracturing occurred on 9 June 2015

During the year, the Company demonstrated a high level of environmental and good level of administrative performance with the relevant resource consent as defined in Section 1.1.4.

3.3 Recommendations from the 2013-2015 Annual Report

In the 2013-2015 Annual Report, it was recommended:

1. THAT no further monitoring be carried out in relation to previously undertaken hydraulic fracturing events at the Kaimiro-A wellsite. Monitoring should recommence however if any further fracturing is undertaken at the site.

   Monitoring recommenced due to the hydraulic fracturing of the Kaimiro-1 well on 9 June 2015. A new consent was issued 29 June 2015.

2. THAT the option for a review of resource consents in June 2015, as set out in condition 16 of consent 9413-1, is not exercised, on the grounds that the current conditions of the consent are adequate to ensure that any significant adverse effects on the environment are avoided.

   There was no review of resource consent 9413-1, during the 2014-2015 or 2015-2016 period as it was deemed that the conditions the consent were adequate to deal with the potential adverse effects of the activity.

3.4 Alterations to monitoring programme

In designing and implementing the monitoring programmes for air/water discharges in the region, the Council has taken into account the extent of information made available by previous authorities, its relevance under the RMA, its obligations to monitor emissions/discharges and effects under the RMA, and report to the regional community. The Council also takes into account the scope of assessments required at the time of renewal of permits, and the need to maintain a sound understanding of industrial processes within Taranaki emitting to the atmosphere/discharging to the environment.

It is proposed that no further monitoring should be undertaken in relation to the hydraulic fracturing of the Kaimiro-1 well. Monitoring should recommence however if any further fracturing is undertaken at the site.

3.5 Exercise of optional review of consent

Resource consent 9413-1 for hydraulic fracturing activities at the Kaimiro-A wellsite was replaced by Consent 10308-1 on 29 June 2016. The new consent provides for an optional review of the consent an annual basis, with the next optional review date being June 2017. Condition 20 of the consent allows the Council to review consent conditions to ensure they are adequate to deal with any significant adverse effects on the environment arising from the exercise of this consent, which were either not foreseen at the time the application was considered or which it was not appropriate to deal with at the time. The Council can also review the consent in order to further specify the best practicable option and/or to ensure that hydraulic fracturing operations appropriately take into account any best practice guidance published by a recognised industry association or environmental regulator.

Following an assessment of the current consent conditions and the results of monitoring undertaken over the period under review, it is considered that there are no grounds that require a review to be pursued or grounds to exercise the review option.

4. Recommendations

1. THAT no further monitoring should be undertaken in relation to the hydraulic fracturing of the Kaimiro-1 well. Monitoring should recommence however if any further fracturing is undertaken at the site.

2. THAT the option for a review of resource consent 10308-1, as set out in condition 20 of the consent, not be exercised, on the grounds that the current conditions of the consent are adequate to ensure that any significant adverse effects on the environment are avoided.

Glossary of common terms and abbreviations

The following abbreviations and terms may be used within this report:

Biomonitoring	Assessing the health of the environment using aquatic organisms.
bbls	Barrel. Unit of measure used in the oil and gas industry (equivalent to approximately 159 litres).
Fresh	Elevated flow in a stream, such as after heavy rainfall.
g/m^3	Grams per cubic metre, and equivalent to milligrams per litre (mg/L). In water, this is also equivalent to parts per million (ppm), but the same does not apply to gaseous mixtures.
Incident	An event that is alleged or is found to have occurred that may have actual or potential environmental consequences or may involve non-compliance with a consent or rule in a regional plan. Registration of an incident by the Council does not automatically mean such an outcome had actually occurred.
Intervention	Action/s taken by Council to instruct or direct actions be taken to avoid or reduce the likelihood of an incident occurring.
Investigation	Action taken by Council to establish the circumstances/events surrounding an incident including any allegations of an incident.
Macroinvertebrate	An invertebrate that is large enough to be seen without the use of a microscope.
MCI	Macroinvertebrate community index; a numerical indication of the state of biological life in a stream that takes into account the sensitivity of the taxa present to organic pollution in stony habitats.
mS/m	Millisiemens per metre.
m^3	Cubic metre (1,000 litres).
pH	A numerical system for measuring acidity in solutions, with 7 as neutral. Numbers lower than 7 are increasingly acidic and higher than 7 are increasingly alkaline. The scale is logarithmic i.e. a change of 1 represents a ten-fold change in strength. For example, a pH of 4 is ten times more acidic than a pH of 5.
Resource consent	Refer Section 87 of the RMA. Resource consents include land use consents (refer Sections 9 and 13 of the RMA), coastal permits (Sections 12, 14 and 15), water permits (Section 14) and discharge permits (Section 15).
RMA	*Resource Management Act 1991* and including all subsequent amendments.
SQMCI	Semi quantitative macroinvertebrate community index.

For further information on analytical methods, contact the Council's laboratory.

Bibliography and references

Greymouth Petroleum Limited (2015) Technical Proposal – Kaimiro-1

Greymouth Petroleum Limited (2014) Kaimiro-1 Post-Fracturing Discharge Report

Stark JD, (1998) SQMCI: a biotic index for freshwater macroinvertebrate coded abundance data. *New Zealand Journal of Marine and Freshwater Research 32(1)*: 55-66

Taranaki Regional Council (2015) Biomonitoring of two unnamed tributaries of the Mangaoraka Stream in relation to hydraulic fracturing at the Kaimiro-A wellsite, October 2015. Report DS035.

Taranaki Regional Council (2014) Greymouth Petroleum Limited Hydraulic Fracturing - Kaimiro-A Wellsite Water Quality Monitoring Programme.

Taranaki Regional Council (2015) Greymouth Petroleum Limited Kaimiro-A Hydraulic Fracturing Monitoring Programme Report 2013-2015. Technical Report 2015-06.

Appendix I

Resource consent held by Greymouth Petroleum Limited

(For a copy of the signed resource consent please contact the TRC Consents department)

Discharge Permit
Pursuant to the Resource Management Act 1991
a resource consent is hereby granted by the
Taranaki Regional Council

Name of Consent Holder:	Greymouth Petroleum Limited P O Box 3394 NEW PLYMOUTH 4341
Decision Date:	25 February 2013
Commencement Date:	25 February 2013

Conditions of Consent

Consent Granted:	To discharge contaminants associated with hydraulic fracturing activities into land at depths greater than 3140 mTVDss beneath the Kaimiro-A wellsite
Expiry Date:	1 June 2020
Review Date(s):	June annually
Site Location:	Kaimiro-A wellsite, 1180 Upland Road, Inglewood
Legal Description:	Lot 4 DP 436344 (Discharge source & site)
Grid Reference (NZTM)	1699694E-5664338N
Catchment:	Waiongana
Tributary:	Mangaoraka

For General, Standard and Special conditions
pertaining to this consent please see reverse side of this document

General condition

a. The consent holder shall pay to the Taranaki Regional Council [the Council] all the administration, monitoring and supervision costs of this consent, fixed in accordance to section 36 of the Resource Management Act.

Special conditions

1. The discharge point shall be deeper than 3140 mTVDss.

   Note: mTVDss = metres true vertical depth subsea, i.e. the true vertical depth in metres below mean sea level.

2. There shall be no discharge of hydraulic fracturing fluids into the reservoir after 1 June 2015.

3. The consent holder shall ensure that the exercise of this consent does not result in contaminants reaching any useable fresh water (groundwater or surface water). Useable fresh groundwater is defined as any groundwater having a Total Dissolved Solids concentration of less than 1000 mg/l.

4. The consent holder shall undertake a programme of sampling and testing that monitors the effects of the exercise of this consent on fresh water resources to assess compliance with condition 3 (the 'Monitoring Programme'). The Monitoring Programme shall be certified by the Chief Executive, Taranaki Regional Council ('the Chief Executive'), before this consent is exercised, and shall include:

   (a) the location of the discharge point(s);
   (b) the location of sampling sites; and
   (c) sampling frequency with reference to a hydraulic fracturing programme.

5. The Monitoring Programme shall include sampling of groundwater from a dedicated monitoring bore established for the purpose. The bore shall be between 20 metres and 50 metres deep, installed in accordance with NZS 4411:2001 and at a location established after consultation with the Chief Executive, Taranaki Regional Council.

6. All water samples taken for monitoring purposes shall be taken in accordance with recognised field procedures and analysed for:

   (a) pH;
   (b) conductivity;
   (c) total dissolved solids;
   (d) major ions (Ca, Mg, K, Na, total alkalinity, bromide, chloride, nitrate-nitrogen, and sulphate);
   (e) trace metals (barium, copper, iron, manganese, nickel, and zinc);
   (f) total petroleum hydrocarbons;
   (g) formaldehyde;
   (h) dissolved methane and ethane gas;
   (i) methanol;
   (j) glycols;
   (k) benzene, toluene, ethylbenzene, and xylenes (BTEX); and

(l) carbon-13 composition of any dissolved methane gas discovered ($^{13}C-CH_4$).

<u>Note</u>: *The samples required, under conditions 4 and 6 could be taken and analysed by the Council or other contracted party on behalf of the consent holder.*

7. All sampling and analysis shall be undertaken in accordance with a Sampling and Analysis Plan, which shall be submitted to the Chief Executive for review and certification before the first sampling is undertaken. This plan shall specify the use of standard protocols recognised to constitute good professional practice including quality control and assurance. An International Accreditation New Zealand (IANZ) accredited laboratory shall be used for all sample analysis. Results shall be provided to the Chief Executive within 30 days of sampling and shall include supporting quality control and assurance information. These results will be used to assess compliance with condition 3.

<u>Note</u>: *The Sampling and Analysis Plan may be combined with the Monitoring Programme required by condition 4.*

8. The consent holder shall undertake well and equipment pressure testing prior to any hydraulic fracture programme on a given well to ensure any discharge will not affect the integrity of the well and hydraulic fracturing equipment.

9. Any hydraulic fracture discharge shall only occur after the consent holder has provided a comprehensive 'Pre-fracturing discharge report' to the Chief Executive. The report shall be provided at least 14 days before the discharge is proposed to commence and shall detail the hydraulic fracturing programme proposed, including as a minimum:

(a) the specific well in which each discharge is to occur, the intended fracture interval(s) ('fracture interval' is the discrete subsurface zone to receive a hydraulic fracture treatment), and the duration of the hydraulic fracturing programme;
(b) the number of discharges proposed and the geographical position (i.e. depth and lateral position) of each intended discharge point;
(c) the total volume of fracture fluid planned to be pumped down the well, including mini- fracture treatments, and their intended composition, including a list of all contaminants and Material Safety Data Sheets for all the chemicals to be used;
(d) the results of the reviews required by condition 14;
(e) results of modelling showing an assessment of the likely extent and dimensions of the fractures that will be generated by the discharge;
(f) the preventative and mitigation measures to be in place to ensure the discharge does not cause adverse environmental effects and complies with condition 3;
(g) the extent and permeability characteristics of the geology above the discharge point to the surface;
(h) any identified faults within the modeled fracture length plus a margin of 50%, and the potential for adverse environmental effects due to the presence of the identified faults;
(i) the burst pressure of the well and the anticipated maximum well and discharge pressures and the duration of the pressures; and
(j) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal.

Note: For the avoidance of doubt, the information provided with a resource consent application would usually be sufficient to constitute a 'Pre-fracturing discharge report' for any imminent hydraulic fracturing discharge. The Pre-fracturing discharge report provided for any later discharge may refer to the resource consent application or earlier Pre-fracturing discharge reports noting any differences.

10. The consent holder shall notify the Taranaki Regional Council of each discharge by emailing worknotification@trc.govt.nz. Notification shall include the date that the discharge is to occur and identify the 'Pre-fracturing discharge report', required by condition 9, which details the discharge. Where practicable and reasonable notice shall be given between 3 days and 14 days before the discharge occurs, but in any event 24 hours notice shall be given.

11. At the conclusion of a hydraulic fracturing programme on a given well, the consent holder shall submit a comprehensive 'Post-fracturing discharge report' to the Chief Executive. The report shall be provided within 60 days after the programme is completed and, as a minimum, shall contain:

(a) confirmation of the interval(s) where fracturing occurred for that programme, and the geographical position (i.e. depth and lateral position) of the discharge point for each fracture interval;
(b) the contaminant volumes and compositions discharged into each fracture interval;
(c) the volume of return fluids from each fracture interval;
(d) an analysis for the constituents set out in conditions 6(a)to 6(k), in a return fluid sample taken within the first two hours of flow back, for each fracture interval if flowed back individually, or for the well if flowed back with all intervals comingled;
(e) an estimate of the volume of fluids (and proppant) remaining underground;
(f) the volume of water produced with the hydrocarbons (produced water) over the period beginning at the start of the hydraulic fracturing programme and ending 50 days after the programme is completed or after that period of production;
(g) an assessment of the extent and dimensions of the fractures that were generated by the discharge, based on modelling undertaken after the discharge has occurred and other diagnostic techniques, including production analysis, available to determine fracture length, height and containment;
(h) the results of pressure testing required by condition 8, and the top hole pressure (psi), slurry rate (bpm), surface proppant concentration (lb/gal), bottom hole proppant concentration (lb/gal), and calculated bottomhole pressure (psi), as well as predicted values for each of these parameters; prior to, during and after each hydraulic fracture treatment;
(i) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal;
(j) details of any incidents where hydraulic fracture fluid is unable to pass through the well perforations (screen outs) that occurred, their likely cause and implications for compliance with conditions 1 and 3; and
(k) an assessment of the effectiveness of the mitigation measures in place with specific reference to those described in the application for this consent.

12. The reports described in conditions 9 and 11 shall be emailed to consents@trc.govt.nz with a reference to the number of this consent.

13. The consent holder shall provide access to a location where the Taranaki Regional Council officers can obtain a sample of the hydraulic fracturing fluids and the return fluids.

14. The consent holder shall at all times adopt the best practicable option, as defined in section 2 of the Resource Management Act 1991, to prevent or minimize any actual or likely adverse effect of the activity on the environment by, as a minimum, ensuring that:

(a) the discharge is contained within the fracture interval;
(b) regular reviews are undertaken of the preventative and mitigation measures adopted to ensure the discharge does not cause adverse environmental effects; and
(c) regular reviews of the chemicals used are undertaken with a view to reducing the toxicity of the chemicals used.

15. The fracture fluid shall be comprised of no less than 95% water and proppant by volume.

16. The Taranaki Regional Council may review any or all of the conditions of this consent by giving notice of review during the month of June each year, for the purposes of:

(a) ensuring that the conditions are adequate to deal with any significant adverse effects on the environment arising from the exercise of this consent, which were either not foreseen at the time the application was considered or which it was not appropriate to deal with at the time; and/or

(b) further specifying the best practicable option as required by condition 14; and/or

(c) ensuring hydraulic fracturing operations appropriately take into account any best practice guidance published by a recognised industry association or environmental regulator.

Signed at Stratford on 25 February 2013

For and on behalf of
Taranaki Regional Council

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Director-Resource Management

Discharge Permit
Pursuant to the Resource Management Act 1991 a resource consent is hereby granted by the Taranaki Regional Council

Name of Consent Holder:	Greymouth Petroleum Acquisition Company Limited PO Box 3394 New Plymouth 4341
Decision Date:	29 June 2016
Commencement Date:	29 June 2016

Conditions of Consent

Consent Granted:	To discharge water based hydraulic fracturing fluids into land at depths greater than 3,232 mTVDss beneath the Kaimiro-A wellsite
Expiry Date:	1 June 2032
Review Date(s):	June annually and in accordance with special condition 20
Site Location:	Kaimiro-A wellsite, 1184 Upland Road, Egmont Village
Grid Reference (NZTM)	1699670E-5664267N
Catchment:	Waiongana
Tributary:	Mangaoraka

For General, Standard and Special conditions pertaining to this consent please see reverse side of this document

General condition

a. The consent holder shall pay to the Taranaki Regional Council all the administration, monitoring and supervision costs of this consent, fixed in accordance with section 36 of the Resource Management Act 1991.

Special conditions

1. The discharge point shall be deeper than 3,232 mTVDss.

   Note: mTVDss = metres true vertical depth subsea, i.e., the true vertical depth in metres below mean sea level.

2. There shall be no discharge of hydraulic fracturing fluids after 1 June 2027.

3. If the GeoNet seismic monitoring network records a seismic event higher than a Modified Mercalli intensity of magnitude 3.0 within 5 km of the geographical position (in 3 dimensions) of any hydraulic fracturing discharge, then:

   (a) if a hydraulic fracturing discharge is currently being undertaken it shall cease immediately and not recommence; or

   (b) if a hydraulic fracturing discharge has occurred within the previous 72 hours no further hydraulic fracturing discharges shall occur.

4. Following the occurrence of any seismic event described in special condition 3 the consent holder shall investigate and report to the Chief Executive, Taranaki Regional Council on the likelihood of the seismic event being induced by the exercise of this consent. Hydraulic fracturing discharges may only then continue once the Chief Executive, Taranaki Regional Council has considered the report and concluded that the environmental risk of recommencing hydraulic fracturing is acceptable and has advised the consent holder accordingly.

5. The consent holder shall ensure that the exercise of this consent does not result in contaminants reaching any useable fresh water (groundwater or surface water). Usable fresh groundwater is defined as any groundwater having a Total Dissolved Solids concentration of less than 1,000 mg/l.

6. The consent holder shall undertake a programme of sampling and testing that monitors the effects of the exercise of this consent on fresh water resources to assess compliance with condition 5 (the 'Monitoring Programme'). The Monitoring Programme shall be certified by the Chief Executive, Taranaki Regional Council, before this consent is exercised, and shall include:

   (a) the location of the discharge point(s);
   (b) the location of sampling sites; and
   (c) sampling frequency with reference to a hydraulic fracturing programme.

7. Depending on the suitability of existing bores within 500 metres of the wellsite for obtaining a representative groundwater sample, it may be necessary for the Monitoring Programme to include installation of, and sampling from, at least one monitoring bore. The bore(s) would be of a depth, location and design determined after consultation with the Chief Executive, Taranaki Regional Council and installed in accordance with NZS 4411:2001.

8. All water samples taken for monitoring purposes shall be taken in accordance with recognised field procedures and analysed for:

   (a) pH;
   (b) conductivity;
   (c) total dissolved solids;
   (d) major ions (Ca, Mg, K, Na, total alkalinity, bromide, chloride, nitrate-nitrogen, and sulphate);
   (e) trace metals (barium, copper, iron, manganese, nickel, and zinc);
   (f) total petroleum hydrocarbons;
   (g) formaldehyde;
   (h) dissolved methane and ethane gas;
   (i) methanol;
   (j) glycols;
   (k) benzene, toluene, ethylbenzene, and xylenes (BTEX); and
   (l) carbon-13 composition of any dissolved methane gas discovered (^{13}C-CH_4).

   <u>Note</u>: *The samples required, under conditions of this consent could be taken and analysed by the Taranaki Regional Council or other contracted party on behalf of the consent holder.*

9. All sampling and analysis shall be undertaken in accordance with a *Sampling and Analysis Plan*, which shall be submitted to the Chief Executive, Taranaki Regional Council for review and certification before the first sampling is undertaken. The plan shall specify the use of standard protocols recognised to constitute good professional practice including quality control and assurance. An International Accreditation New Zealand (IANZ) accredited laboratory shall be used for all sample analysis. Results shall be provided to the Chief Executive, Taranaki Regional Council within 30 days of sampling and shall include supporting quality control and assurance information. These results will be used to assess compliance with condition 5.

   <u>Note:</u> *The Sampling and Analysis Plan may be combined with the Monitoring Programme required by* condition 6.

10. The consent holder shall undertake well and equipment pressure testing prior to any hydraulic fracture programme on a given well to ensure any discharge will not affect the integrity of the well and hydraulic fracturing equipment.

11. Any hydraulic fracture discharge shall only occur after the consent holder has provided a comprehensive 'Pre-fracturing Discharge Report' to the Chief Executive, Taranaki Regional Council. The report shall be provided at least 14 days before the discharge is proposed to commence and shall detail the hydraulic fracturing programme proposed, including as a minimum:

    (a) the specific well in which each discharge is to occur, the intended fracture interval(s) ('fracture interval' is the discrete subsurface zone to receive a hydraulic fracture treatment), and the duration of the hydraulic fracturing programme;
    (b) the number of discharges proposed and the geographical position (i.e. depth and lateral position) of each intended discharge point;
    (c) the total volume of fracture fluid planned to be pumped down the well, including mini-fracture treatments, and their intended composition, including a list of all contaminants and Material Safety Data Sheets for all the chemicals to be used;
    (d) the monitoring techniques to be used to determine the fate of discharged material;
    (e) the results of the reviews required by condition 17;
    (f) results of modelling showing an assessment of the likely extent and dimensions of the fractures that will be generated by the discharge;
    (g) the preventative and mitigation measures to be in place to ensure the discharge does not cause adverse environmental effects and complies with condition 5;
    (h) the extent and permeability characteristics of the geology above the discharge point to the surface;
    (i) any identified faults within the modelled fracture length plus a margin of 50%, and the potential for adverse environmental effects due to the presence of the identified faults;
    (j) the burst pressure of the well casing and the anticipated maximum well and discharge pressures and the duration of the pressures; and
    (k) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal; and
    (l) details why the contaminants in the discharge and the monitoring techniques used comply with condition 17.

    Note: *For the avoidance of doubt, the information provided with a resource consent application would usually be sufficient to constitute a 'Pre-fracturing Discharge Report' for any imminent hydraulic fracturing discharge. The Pre-fracturing Discharge Report provided for any later discharge may refer to the resource consent application or earlier Pre-fracturing Discharge Reports noting any differences.*

12. The consent holder shall notify the Taranaki Regional Council of the date that each discharge is intended to commence by emailing worknotification@trc.govt.nz. Notification also shall identify the 'Pre-fracturing Discharge Report', required by condition 0, which details the discharge and be given no less than 3 days before the intended discharge date. If any discharge occurs more than 30 days after the notification date, additional notification as specified in this condition is required.

13. Subject to condition 14, within 90 days of any commencement date as advised under condition 12, the consent holder shall submit a comprehensive 'Post-fracturing Discharge Report' to the Chief Executive, Taranaki Regional Council. The report shall, as a minimum, contain:

    (a) date and time of discharge;
    (b) confirmation of the interval(s) where fracturing occurred for that programme, and the geographical position (i.e., depth and lateral position) of the discharge point for each fracture interval;
    (c) the contaminant volumes and composition of fluid discharged into each fracture interval;
    (d) the volume of return fluids from each fracture interval;
    (e) an analysis for the constituents set out in conditions 8(a) to 8(k), in a return fluid sample taken within the first two hours of flow back, for each fracture interval if flowed back individually, or for the well if flowed back with all intervals comingled;
    (f) an estimate of the volume of fluids (and proppant) remaining underground;
    (g) the volume of water produced with the hydrocarbons (produced water) over the period beginning at the start of the hydraulic fracturing programme and ending 30 days after the programme is completed or after that period of production;
    (h) an assessment of the extent and dimensions of the fractures that were generated by the discharge, based on modelling undertaken after the discharge has occurred and other diagnostic techniques, including production analysis, available to determine fracture length, height and containment;
    (i) the results of pressure testing required by condition 10 and the top-hole pressure (psi), slurry rate (bpm), surface proppant concentration (lb/gal), bottom hole proppant concentration (lb/gal), and calculated bottom hole pressure (psi), as well as predicted values for each of these parameters; prior to, during and after each hydraulic fracture treatment;
    (j) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal;
    (k) details of any incidents where hydraulic fracture fluid is unable to pass through the well perforations (screen outs) that occurred, their likely cause and implications for compliance with conditions 1 and 5; and
    (l) results of the monitoring referred to in condition 11 (d); and
    (m) an assessment of the effectiveness of the mitigation measures in place with specific reference to those described in the application for this consent.

14. On occasions, including for programs involving multiple hydraulic fracturing discharges, more than one 'Post-fracturing discharge report' may be required in order to meet the 90-day deadline from commencement required by condition 13. In these situations the consent holder shall submit an 'Interim Post-fracturing Discharge Report', which includes all the information that is available, to the Chief Executive, Taranaki Regional Council within 90 days and a final Post-fracturing report as soon as practicable but within 90 days of the interim report.

15. The reports described in conditions 11 and 13 shall be emailed to consents@trc.govt.nz with a reference to the number of this consent.

16. The consent holder shall provide access to a location where the Taranaki Regional Council officers can obtain a sample of the hydraulic fracturing fluids and the return fluids.

17. The consent holder shall at all times adopt the best practicable option, as defined in section 2 of the Resource Management Act 1991, to prevent or minimize any actual or likely adverse effect of the activity on the environment by, as a minimum, ensuring that:

    (a) the discharge is contained within the fracture interval;
    (b) regular reviews of monitoring techniques used to ensure the discharge does not cause adverse environmental effects are undertaken;
    (c) regular reviews are undertaken of the preventative and mitigation measures adopted to ensure the discharge does not cause adverse environmental effects; and
    (d) regular reviews of the chemicals used are undertaken with a view to reducing the toxicity of the chemicals used.

18. The fracture fluid shall be comprised of no less than 95% water and proppant by volume.

19. This consent shall lapse on 30 June 2021, unless the consent is given effect to before the end of that period or the Taranaki Regional Council fixes a longer period pursuant to section 125(1)(b) of the Resource Management Act 1991.

20. The Taranaki Regional Council may review any or all of the conditions of this consent by giving notice of review:

    a) during the month of June each year, and/or
    b) within 30 days of receiving any investigation and report in accordance with condition 4 above;

    for the purposes of:

    (a) ensuring that the conditions are adequate to deal with any significant adverse effects on the environment arising from the exercise of this consent, which were either not foreseen at the time the application was considered or which it was not appropriate to deal with at the time; and/or

    (b) further specifying the best practicable option as required by condition 17; and/or

    (c) ensuring hydraulic fracturing operations appropriately take into account any best practice guidance published by a recognised industry association or environmental regulator.

Signed at Stratford on 29 June 2016

For and on behalf of
Taranaki Regional Council

____

A D McLay
Director - Resource Management

Appendix II

Certificates of analysis - groundwater

Hill Laboratories
BETTER TESTING BETTER RESULTS

R J Hill Laboratories Limited
1 Clyde Street
Private Bag 3205
Hamilton 3240, New Zealand

Tel +64 7 858 2000
Fax +64 7 858 2001
Email mail@hill-labs.co.nz
Web www.hill-labs.co.nz

ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1416942	SPv2
Contact:	Regan Phipps	**Date Registered:**	24-Apr-2015	
	C/- Taranaki Regional Council	**Date Reported:**	07-May-2015	
	Private Bag 713	**Quote No:**	47915	
	STRATFORD 4352	**Order No:**		
		Client Reference:	Kaimiro A 1 Yr Post HF	
		Submitted By:	Regan Phipps	

Sample Type: Aqueous

Sample Name:		GND2447 23-Apr-2015 12:20 pm				
Lab Number:		1416942.1				
Individual Tests						
Sum of Anions	meq/L	1.72	-	-	-	-
Sum of Cations	meq/L	2.0	-	-	-	-
pH	pH Units	6.6	-	-	-	-
Total Alkalinity	g/m³ as $CaCO_3$	74	-	-	-	-
Bicarbonate	g/m³ at 25°C	91	-	-	-	-
Total Hardness	g/m³ as $CaCO_3$	44	-	-	-	-
Electrical Conductivity (EC)	mS/m	16.9	-	-	-	-
Total Dissolved Solids (TDS)	g/m³	159	-	-	-	-
Dissolved Barium	g/m³	0.0176	-	-	-	-
Dissolved Bromine*	g/m³	0.041	-	-	-	-
Dissolved Calcium	g/m³	10.1	-	-	-	-
Dissolved Copper	g/m³	< 0.0005	-	-	-	-
Dissolved Iron	g/m³	7.7	-	-	-	-
Dissolved Magnesium	g/m³	4.6	-	-	-	-
Dissolved Manganese	g/m³	0.29	-	-	-	-
Dissolved Mercury	g/m³	< 0.00008	-	-	-	-
Dissolved Nickel	g/m³	< 0.0005	-	-	-	-
Dissolved Potassium	g/m³	6.1	-	-	-	-
Dissolved Sodium	g/m³	16.4	-	-	-	-
Dissolved Zinc	g/m³	0.0099	-	-	-	-
Chloride	g/m³	8.0	-	-	-	-
Nitrite-N	g/m³	< 0.2	-	-	-	-
Nitrate-N	g/m³	< 0.2	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	< 0.2 #1	-	-	-	-
Sulphate	g/m³	< 0.5	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	-	-	-	-
Toluene	g/m³	< 0.0010	-	-	-	-
Ethylbenzene	g/m³	< 0.0010	-	-	-	-
m&p-Xylene	g/m³	< 0.002	-	-	-	-

Sample Type: Aqueous						
Sample Name:		GND2447 23-Apr-2015 12:20 pm				
Lab Number:		1416942.1				
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m³	< 0.0010	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m³	< 0.02	-	-	-	-
Gases in groundwater						
Ethane	g/m³	< 0.003	-	-	-	-
Ethylene	g/m³	< 0.004	-	-	-	-
Methane	g/m³	5.7	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.10	-	-	-	-
C10 - C14	g/m³	< 0.2	-	-	-	-
C15 - C36	g/m³	< 0.4	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	< 0.7	-	-	-	-

Analyst's Comments

[#1] Severe matrix interferences required that a dilution be performed prior to analysis, resulting in a detection limit higher than that normally achieved for the NOxN /NO2N analysis.

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m³	1
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m³	1
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m³	1
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m³	1
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1
Total anions for anion/cation balance check	Calculation: sum of anions as mEquiv/L calculated from Alkalinity (bicarbonate), Chloride and Sulphate. Nitrate-N, Nitrite-N. Fluoride, Dissolved Reactive Phosphorus and Cyanide also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.07 meq/L	1
Total cations for anion/cation balance check	Sum of cations as mEquiv/L calculated from Sodium, Potassium, Calcium and Magnesium. Iron, Manganese, Aluminium, Zinc, Copper, Lithium, Total Ammoniacal-N and pH (H^+) also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.05 meq/L	1
pH	pH meter. APHA 4500-H^+ B 22nd ed. 2012.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D 22nd ed. 2012.	1.0 g/m³ at 25°C	1
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	1
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22nd ed. 2012.	10 g/m³	1
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.00010 g/m³	1

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.005 g/m^3	1
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m^3	1
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m^3	1
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m^3	1
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m^3	1
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m^3	1
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m^3	1
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0010 g/m^3	1
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m^3	1
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m^3	1
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	1
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m^3	1
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22nd ed. 2012.	0.5 g/m^3	1

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

Ara Heron BSc (Tech)
Client Services Manager - Environmental Division

R J Hill Laboratories Limited
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Tel +64 7 858 2000
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Email mail@hill-labs.co.nz
Web www.hill-labs.co.nz

ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1609821 SPv1
Contact:	David Olson	**Date Registered:**	04-Jul-2016
	C/- Taranaki Regional Council	**Date Reported:**	13-Jul-2016
	Private Bag 713	**Quote No:**	47915
	Stratford 4352	**Order No:**	
		Client Reference:	Kaimiro - A 1 Year Post Frac GW
		Submitted By:	David Olson

Sample Type: Aqueous

Sample Name:		GND2447 01-Jul-2016 11:45 am				
Lab Number:		1609821.1				
Individual Tests						
Sum of Anions	meq/L	1.80 #1	-	-	-	-
Sum of Cations	meq/L	2.3 #1	-	-	-	-
pH	pH Units	7.1	-	-	-	-
Total Alkalinity	g/m³ as $CaCO_3$	78	-	-	-	-
Bicarbonate	g/m³ at 25°C	95	-	-	-	-
Total Hardness	g/m³ as $CaCO_3$	47	-	-	-	-
Electrical Conductivity (EC)	mS/m	17.8	-	-	-	-
Total Dissolved Solids (TDS)	g/m³	167	-	-	-	-
Dissolved Barium	g/m³	0.023	-	-	-	-
Dissolved Bromine*	g/m³	0.038	-	-	-	-
Dissolved Calcium	g/m³	10.5	-	-	-	-
Dissolved Copper	g/m³	< 0.0005	-	-	-	-
Dissolved Iron	g/m³	10.6	-	-	-	-
Dissolved Magnesium	g/m³	5.0	-	-	-	-
Dissolved Manganese	g/m³	0.31	-	-	-	-
Dissolved Mercury	g/m³	< 0.00008	-	-	-	-
Dissolved Nickel	g/m³	< 0.0005	-	-	-	-
Dissolved Potassium	g/m³	6.9	-	-	-	-
Dissolved Sodium	g/m³	18.5	-	-	-	-
Dissolved Zinc	g/m³	0.0067	-	-	-	-
Chloride	g/m³	8.7	-	-	-	-
Nitrite-N	g/m³	0.004	-	-	-	-
Nitrate-N	g/m³	< 0.002	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	0.004	-	-	-	-
Sulphate	g/m³	< 0.5	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	-	-	-	-
Toluene	g/m³	< 0.0010	-	-	-	-
Ethylbenzene	g/m³	< 0.0010	-	-	-	-
m&p-Xylene	g/m³	< 0.002	-	-	-	-

Sample Type: Aqueous						
Sample Name:		GND2447 01-Jul-2016 11:45 am				
Lab Number:		1609821.1				
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m^3	< 0.0010	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m^3	< 0.02	-	-	-	-
Gases in groundwater						
Ethane	g/m^3	< 0.003	-	-	-	-
Ethylene	g/m^3	< 0.004	-	-	-	-
Methane	g/m^3	3.5	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m^3	< 0.10	-	-	-	-
C10 - C14	g/m^3	< 0.2	-	-	-	-
C15 - C36	g/m^3	< 0.4	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m^3	< 0.7	-	-	-	-

Analyst's Comments

[#1] It was noted that some of the anion / cation balances did not agree to within expected limits. This was largely attributed to the high levels of dissolved iron. We have included dissolved iron in the cation balance equations. However, the precipitation of large amounts of iron in the unpreserved containers (soon after sampling) will result in the loss of ions from solution and consumption of alkalinity. This may well result in the lower anions relative to the cations, being reported. The loss of soluble iron in the unpreserved container does not affect the cation balance, as the dissolved iron is sampled into an acid preserved container, stabilising the iron in solution.

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m^3	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m^3	1
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m^3	1
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m^3	1
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m^3	1
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1
Total anions for anion/cation balance check	Calculation: sum of anions as mEquiv/L calculated from Alkalinity (bicarbonate), Chloride and Sulphate. Nitrate-N, Nitrite-N. Fluoride, Dissolved Reactive Phosphorus and Cyanide also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.07 meq/L	1
Total cations for anion/cation balance check	Sum of cations as mEquiv/L calculated from Sodium, Potassium, Calcium and Magnesium. Iron, Manganese, Aluminium, Zinc, Copper, Lithium, Total Ammoniacal-N and pH (H^+) also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.05 meq/L	1
pH	pH meter. APHA 4500-H^+ B 22nd ed. 2012. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22nd ed. 2012.	1.0 g/m^3 as $CaCO_3$	1
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D 22nd ed. 2012.	1.0 g/m^3 at 25°C	1
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m^3 as $CaCO_3$	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	1

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22nd ed. 2012.	10 g/m^3	1
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.00010 g/m^3	1
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.005 g/m^3	1
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m^3	1
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m^3	1
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m^3	1
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m^3	1
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m^3	1
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m^3	1
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0010 g/m^3	1
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m^3	1
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m^3	1
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	1
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m^3	1
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22nd ed. 2012.	0.5 g/m^3	1

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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ANALYSIS REPORT

SPv1

Client:	Taranaki Regional Council	**Lab No:**	1473068
Contact:	Regan Phipps	**Date Registered:**	09-Sep-2015
	C/- Taranaki Regional Council	**Date Reported:**	17-Sep-2015
	Private Bag 713	**Quote No:**	47915
	STRATFORD 4352	**Order No:**	
		Client Reference:	Kaimiro A - 3 Month Post HF
		Submitted By:	R McDonnell

Sample Type: Aqueous

Sample Name:		GND2447 08-Sep-2015 10:10 am				
Lab Number:		1473068.1				
Individual Tests						
Sum of Anions	meq/L	1.81	-	-	-	-
Sum of Cations	meq/L	2.2	-	-	-	-
pH	pH Units	6.7	-	-	-	-
Total Alkalinity	g/m³ as $CaCO_3$	78	-	-	-	-
Bicarbonate	g/m³ at 25°C	95	-	-	-	-
Total Hardness	g/m³ as $CaCO_3$	46	-	-	-	-
Electrical Conductivity (EC)	mS/m	17.7	-	-	-	-
Total Dissolved Solids (TDS)	g/m³	160	-	-	-	-
Dissolved Barium	g/m³	0.022	-	-	-	-
Dissolved Bromine*	g/m³	0.042	-	-	-	-
Dissolved Calcium	g/m³	10.6	-	-	-	-
Dissolved Copper	g/m³	< 0.0005	-	-	-	-
Dissolved Iron	g/m³	9.4	-	-	-	-
Dissolved Magnesium	g/m³	4.8	-	-	-	-
Dissolved Manganese	g/m³	0.30	-	-	-	-
Dissolved Mercury	g/m³	< 0.00008	-	-	-	-
Dissolved Nickel	g/m³	< 0.0005	-	-	-	-
Dissolved Potassium	g/m³	7.2	-	-	-	-
Dissolved Sodium	g/m³	17.7	-	-	-	-
Dissolved Zinc	g/m³	0.0058	-	-	-	-
Chloride	g/m³	8.5	-	-	-	-
Nitrite-N	g/m³	0.006	-	-	-	-
Nitrate-N	g/m³	< 0.002	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	0.005	-	-	-	-
Sulphate	g/m³	< 0.5	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	-	-	-	-
Toluene	g/m³	< 0.0010	-	-	-	-
Ethylbenzene	g/m³	< 0.0010	-	-	-	-
m&p-Xylene	g/m³	< 0.002	-	-	-	-

Sample Type: Aqueous						
Sample Name:		GND2447 08-Sep-2015 10:10 am				
Lab Number:		1473068.1				
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m^3	< 0.0010	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m^3	< 0.02	-	-	-	-
Gases in groundwater						
Ethane	g/m^3	< 0.003	-	-	-	-
Ethylene	g/m^3	< 0.003	-	-	-	-
Methane	g/m^3	5.4	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m^3	< 0.10	-	-	-	-
C10 - C14	g/m^3	< 0.2	-	-	-	-
C15 - C36	g/m^3	< 0.4	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m^3	< 0.7	-	-	-	-

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m^3	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m^3	1
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m^3	1
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m^3	1
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m^3	1
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1
Total anions for anion/cation balance check	Calculation: sum of anions as mEquiv/L calculated from Alkalinity (bicarbonate), Chloride and Sulphate. Nitrate-N, Nitrite-N. Fluoride, Dissolved Reactive Phosphorus and Cyanide also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.07 meq/L	1
Total cations for anion/cation balance check	Sum of cations as mEquiv/L calculated from Sodium, Potassium, Calcium and Magnesium. Iron, Manganese, Aluminium, Zinc, Copper, Lithium, Total Ammoniacal-N and pH (H^+) also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.05 meq/L	1
pH	pH meter. APHA 4500-H^+ B 22nd ed. 2012. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22nd ed. 2012.	1.0 g/m^3 as $CaCO_3$	1
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D 22nd ed. 2012.	1.0 g/m^3 at 25°C	1
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m^3 as $CaCO_3$	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	1
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22nd ed. 2012.	10 g/m^3	1
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.00010 g/m^3	1
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.005 g/m^3	1

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m^3	1
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m^3	1
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m^3	1
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m^3	1
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m^3	1
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m^3	1
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0010 g/m^3	1
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m^3	1
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m^3	1
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	1
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m^3	1
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22nd ed. 2012.	0.5 g/m^3	1

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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Ara Heron BSc (Tech)
Client Services Manager - Environmental Division

Appendix III

Certificates of analysis – hydraulic fracturing and return fluid

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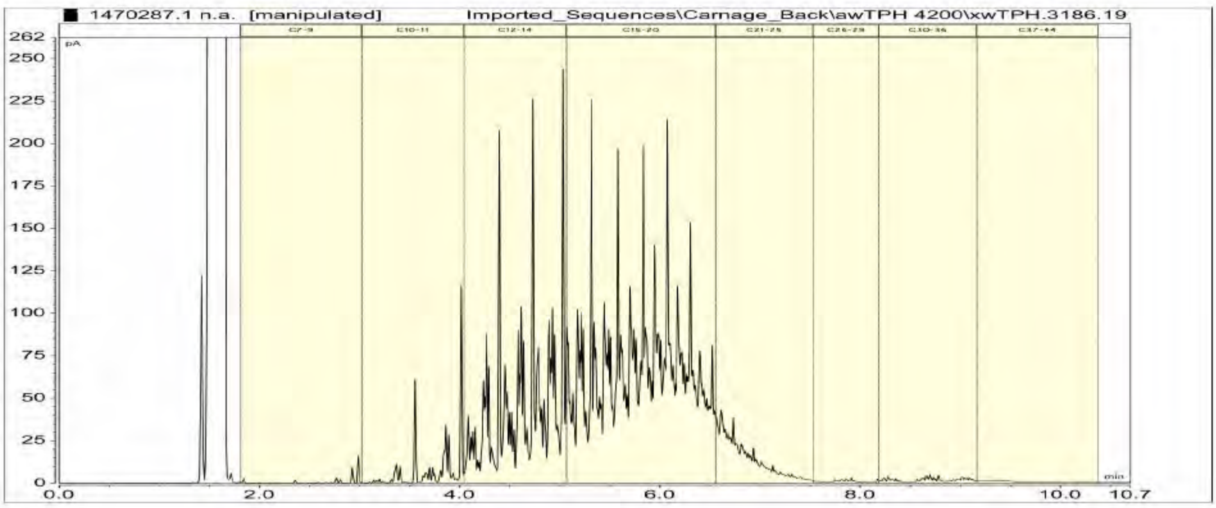
ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1470287 SPv1
Contact:	Regan Phipps	**Date Registered:**	02-Sep-2015
	C/- Taranaki Regional Council	**Date Reported:**	17-Sep-2015
	Private Bag 713	**Quote No:**	50522
	STRATFORD 4352	**Order No:**	
		Client Reference:	Kaimiro A - HF Fluid
		Submitted By:	Regan Phipps

Sample Type: Aqueous

Sample Name:		GND 2460 09-Jun-2015 12:00 pm				
Lab Number:		1470287.1				
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	43	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.010	-	-	-	-
Toluene	g/m³	0.016	-	-	-	-
Ethylbenzene	g/m³	0.018	-	-	-	-
m&p-Xylene	g/m³	< 0.02	-	-	-	-
o-Xylene	g/m³	< 0.010	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	1.38	-	-	-	-
C10 - C14	g/m³	94	-	-	-	-
C15 - C36	g/m³	200	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	300	-	-	-	-

1470287.1
GND 2460 09-Jun-2015 12:00 pm
Client Chromatogram for TPH by FID



Analyst's Comments

The sample was received in a plastic bottle that wasn't completely filled. Please note that glass bottles should be used (and completely filled) for hydrocarbon analysis to avoid loss of volatile compounds and possible plastic contamination.

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m^3	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m^3	1
Total Petroleum Hydrocarbons in Water*	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m^3	1

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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ANALYSIS REPORT

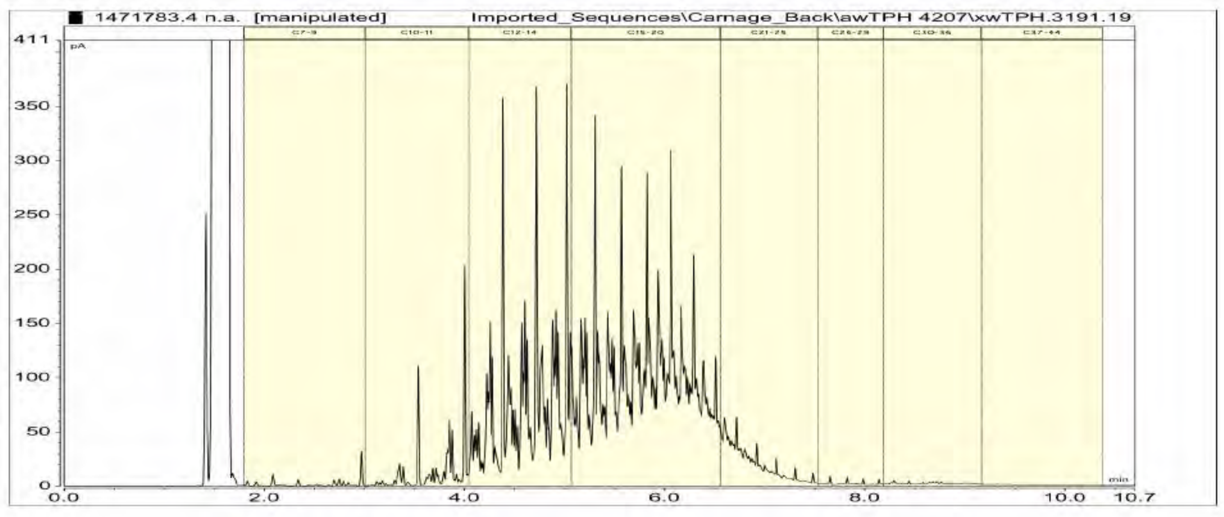
Client:	Taranaki Regional Council	**Lab No:**	1471783 SPv1
Contact:	Regan Phipps	**Date Registered:**	04-Sep-2015
	C/- Taranaki Regional Council	**Date Reported:**	17-Sep-2015
	Private Bag 713	**Quote No:**	71307
	STRATFORD 4352	**Order No:**	
		Client Reference:	Kaimiro A - Return Fluid
		Submitted By:	R McDonnell

Sample Type: Saline

Sample Name:		Composite of GND2460 1/3, GND2460 2/3 & GND2460 3/3				
Lab Number:		1471783.4				
Individual Tests						
pH*	pH Units	6.8	-	-	-	-
Total Alkalinity*	g/m³ as $CaCO_3$	1,680	-	-	-	-
Analysis Temperature for Bicarbonate	°C	23	-	-	-	-
Bicarbonate	g/m³ at Analysis Temperature	1,812	-	-	-	-
Total Hardness*	g/m³ as $CaCO_3$	250	-	-	-	-
Electrical Conductivity (EC)*	mS/m	2,130	-	-	-	-
Total Dissolved Solids (TDS)*	g/m³	14,300	-	-	-	-
Dissolved Barium*	g/m³	21	-	-	-	-
Dissolved Bromine*	g/m³	14.9	-	-	-	-
Dissolved Calcium*	g/m³	79	-	-	-	-
Dissolved Copper*	g/m³	< 0.005	-	-	-	-
Dissolved Iron*	g/m³	11.1	-	-	-	-
Dissolved Magnesium*	g/m³	12	-	-	-	-
Dissolved Manganese*	g/m³	3.4	-	-	-	-
Total Mercury*	g/m³	< 0.011	-	-	-	-
Dissolved Nickel*	g/m³	< 0.03	-	-	-	-
Dissolved Potassium*	g/m³	530	-	-	-	-
Dissolved Sodium*	g/m³	4,500	-	-	-	-
Dissolved Sulphur*	g/m³	8	-	-	-	-
Dissolved Zinc*	g/m³	0.06	-	-	-	-
Chloride*	g/m³	6,300	-	-	-	-
Nitrite-N	g/m³	< 0.002	-	-	-	-
Nitrate-N	g/m³	0.007	-	-	-	-
Nitrate*	g/m³	0.029	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	0.007	-	-	-	-
Sulphate*	g/m³	23	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 20	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 20	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	6	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene*	g/m³	1.71	-	-	-	-
Toluene*	g/m³	0.44	-	-	-	-
Ethylbenzene*	g/m³	0.0178	-	-	-	-

Sample Type: Saline						
Sample Name:		Composite of GND2460 1/3, GND2460 2/3 & GND2460 3/3				
Lab Number:		1471783.4				
BTEX in Water by Headspace GC-MS						
m&p-Xylene*	g/m^3	0.064	-	-	-	-
o-Xylene*	g/m^3	0.037	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde*	g/m^3	0.25	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9*	g/m^3	2.9	-	-	-	-
C10 - C14*	g/m^3	123	-	-	-	-
C15 - C36*	g/m^3	230	-	-	-	-
Total hydrocarbons (C7 - C36)*	g/m^3	350	-	-	-	-

1471783.4
Composite of GND2460 1/3, GND2460 2/3 & GND2460 3/3
Client Chromatogram for TPH by FID



Analyst's Comments

The sample was received in a plastic bottle that wasn't completely filled. Please note that glass bottles should be used (and completely filled) for hydrocarbon analysis to avoid loss of volatile compounds and possible plastic contamination.

Due to the type of matrix found in sample 1471783.4, a dilution was required for the Glycol analysis. Hence the higher detection limits reported.

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Saline

Test	Method Description	Default Detection Limit	Sample No
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	4
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	4
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m^3	4
BTEX in Water by Headspace GC-MS*	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m^3	4
Formaldehyde in Water by DNPH & LCMSMS*	DNPH derivatisation, extraction, LCMSMS	0.02 g/m^3	4
Total Petroleum Hydrocarbons in Water*	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m^3	4
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	4
Total Digestion of Saline Samples*	Nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	4

Sample Type: Saline			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
pH*	Saline water, pH meter. APHA 4500-H^+ B 22nd ed. 2012. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field.	0.1 pH Units	4
Total Alkalinity*	Saline water, Titration to pH 4.5.	1.0 g/m^3 as $CaCO_3$	4
Analysis Temperature for Bicarbonate	Temperature at which Bicarbonate titration was conducted as reported by Geological & Nuclear Sciences, Wairakei.	1.0 °C	4
Bicarbonate	Bicarbonate (HCO3) Titration Method conducted at reported temperature. Subcontracted to Geological & Nuclear Sciences, Wairakei. ASTM Standards D513-82 Vol.11.01 of 1988.	20 g/m^3 at Analysis Temperature	4
Total Hardness*	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m^3 as $CaCO_3$	4
Electrical Conductivity (EC)*	Saline water, Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.10 mS/m	4
Total Dissolved Solids (TDS)*	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22nd ed. 2012.	50 g/m^3	4
Filtration for dissolved metals analysis*	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 22nd ed. 2012.	-	4
Dissolved Barium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.0006 g/m^3	4
Dissolved Bromine*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.10 g/m^3	4
Dissolved Calcium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.0 g/m^3	4
Dissolved Copper*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0010 g/m^3	4
Dissolved Iron*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.004 g/m^3	4
Dissolved Magnesium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.4 g/m^3	4
Dissolved Manganese*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0010 g/m^3	4
Total Mercury*	Nitric acid digestion, ICP-MS, screen level. APHA 3125 B 22nd ed. 2012.	0.0021 g/m^3	4
Dissolved Nickel*	Filtered sample, ICP-MS with universal cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0010 g/m^3	4
Dissolved Potassium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.0 g/m^3	4
Dissolved Sodium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.4 g/m^3	4
Dissolved Sulphur*	Filtered sample, ICP-OES.	0.10 g/m^3	4
Dissolved Zinc*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.004 g/m^3	4
Chloride*	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m^3	4
Nitrite-N	Saline sample. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m^3	4
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	4
Nitrate*	Calculation from Nitrate-N.	0.010 g/m^3	4
Nitrate-N + Nitrite-N	Saline sample. Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m^3	4
Soluble Sulphate*	Calculation: from dissolved sulphur.	2 g/m^3	4

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Ara Heron BSc (Tech)
Client Services Manager - Environmental Division

Appendix IV

Biomonitoring report

To	Job Manager, Conor Lee
From	Freshwater Biologist, Darin Sutherland
Report No	DS035
Doc No	1582577
Date	October 2015

Biomonitoring of two unnamed tributaries of the Mangaoraka Stream in relation to hydraulic fracturing at the Kaimiro-A wellsite, October 2015

Introduction

This survey was performed following hydraulic fracturing activities at the Kaimiro-A wellsite in early October, 2015. Survey results may be compared with those of two biomonitoring survey undertaken in the 2014-2015 monitoring year for the Kaimiro Production Station of Greymouth Petroleum (previously owned by Fletcher Challenge Energy Taranaki Limited); particularly that undertaken in February, 2015. The Taranaki Regional Council has undertaken surveys since January 1985 in the tributaries of the Mangaoraka Stream that receive stormwater and wastewater from the production station area. During 1987 and 1988 oil seepage to these streams disrupted the aquatic communities. Biomonitoring was not undertaken for nearly four years following the oil seepage period, until 1992. The results of surveys performed since the 1998-99 monitoring year are discussed in the references at the end of this report.

Methods

This survey was undertaken on 1 October 2015 at three sites in two unnamed tributaries of the Mangaoraka Stream. Figure 1 shows the location of these sampling sites. Site 1 is the 'control' site which is located in a major tributary of the Mangaoraka Stream, upstream of the confluence with a more minor tributary. Site 2 is situated in the minor tributary which receives the stormwater discharge from the production station and site 3 is approximately 50 metres downstream of the confluence of this tributary (Table 1).

The Council's standard '400ml kick-sampling' technique was used at sites 1, 2 and 3 (Table 1). The 'kick-sampling' technique is very similar to Protocol C1 (hard-bottomed, semi-quantitative) of the New Zealand Macroinvertebrate Working Group (NZMWG) protocols for macroinvertebrate samples in wadeable streams (Stark *et al*, 2001).

Table 1 Biomonitoring sites in two tributaries of the Mangaoraka Stream in relation to discharges from the Kaimiro Production Station

Site	Site code	GPS reference (NZTM)	Location
1	MRK 000198	E1700117 N5664652	Major tributary approx. 50m u/s of confluence with minor tributary
2	MRK 000204	E1700054 N5664636	Minor tributary (receives discharge) 150m d/s of Upland Road
3	MRK 000207	E1700171 N5665679	Major tributary approx. 50m d/s of confluence with minor tributary

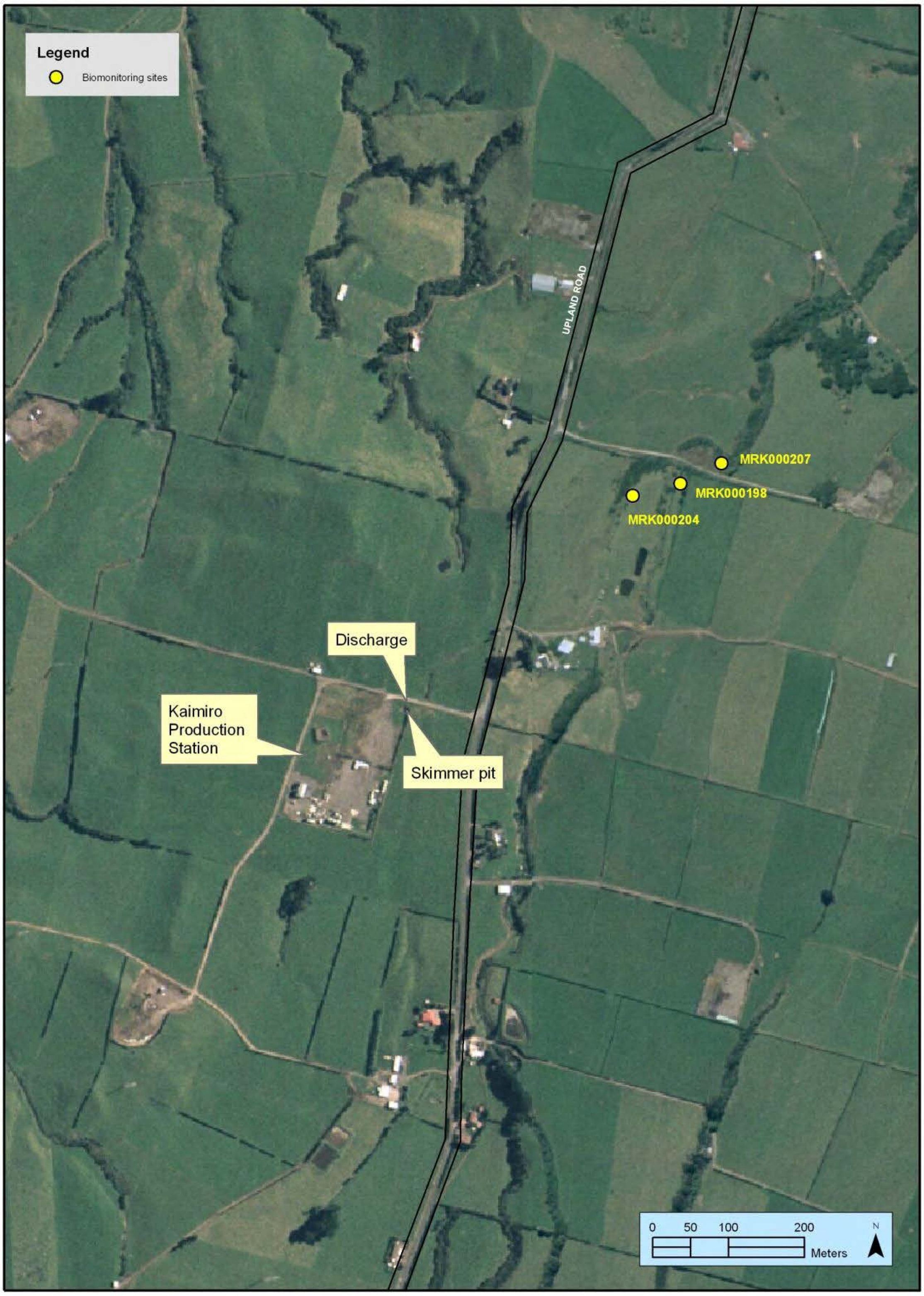

Figure 1 Biomonitoring sites in two unnamed tributaries of the Mangaoraka Stream related to the Kaimiro-A wellsite.

Samples were preserved with Kahle's Fluid for later sorting and identification under a stereomicroscope according to Taranaki Regional Council methodology using protocol P1 of NZMWG protocols for sampling macroinvertebrates in wadeable streams (Stark et al. 2001). Macroinvertebrate taxa found in each sample were recorded as:

R (rare)	= less than 5 individuals;
C (common)	= 5-19 individuals;
A (abundant)	= estimated 20-99 individuals;
VA (very abundant)	= estimated 100-499 individuals;
XA (extremely abundant)	= estimated 500 individuals or more.

Stark (1985) developed a scoring system for macroinvertebrate taxa according to their sensitivity to organic pollution in stony New Zealand streams. Highly 'sensitive' taxa were assigned the highest scores of 9 or 10, while the most 'tolerant' forms scored 1. Sensitivity scores for certain taxa have been modified in accordance with Taranaki experience. Averaging the scores from a list of taxa taken from one site and multiplying by a scaling factor of 20 produces a Macroinvertebrate Community Index (MCI) value. A difference of 11 units or more in MCI values is considered significantly different (Stark 1998).

The MCI was designed for use in stony streams, and all sites sampled in this survey provided stony substrate. The MCI was designed as a measure of the overall sensitivity of macroinvertebrate communities to the effects of organic pollution, though sedimentation, temperatures, current speed, dissolved oxygen levels and some toxins can also affect the index values, because the taxa capable of tolerating extremes in these variables generally have low sensitivity scores. Usually more 'sensitive' communities inhabit less polluted waterways.

A semi-quantitative MCI value ($SQMCI_s$) has also been calculated for the taxa present at each site by multiplying each taxon score by a loading factor (related to its abundance), totalling these products, and dividing by the sum of the loading factors (Stark, 1998 and 1999). The loading factors were 1 for rare (R), 5 for common (C), 20 for abundant (A), 100 for very abundant (VA) and 500 for extremely abundant (XA). Unlike the MCI, the $SQMCI_s$ is not multiplied by a scaling factor of 20, therefore $SQMCI_s$ values range from 1 to 10, while MCI values range from 20 to 200.

Results

Site habitat characteristics and hydrology

This October 2015 survey followed a period of 13 days since a fresh in excess of three times median flow, and 28 days since a fresh in excess of seven times median flow. In the month prior to this survey, there had been four fresh events, two of which exceeded three times median flow and two which exceeded seven times median flow.

There was significant slumping of the banks upstream and downstream of site 1 and to a lesser extent site 2 which had been caused by stock damage. The bank slumping had been noted previously at site 1 in the October 2014 and May 2012 surveys and appears to be an ongoing issue at the site. There was also a dead cow in the stream immediately below site 1 at the time of the survey. The water temperatures were cool (11.4-11.9°C). Water levels were moderate and water speeds were variable among sampling sites. Water was uncoloured and clear for all sites during the survey. Site 1 had a substrate composition comprised mostly of silt and sand, site 2 had a substrate composition which was mainly silt and cobbles and site 3 had predominately silt, cobble and boulder substrate. There was iron oxide sediment covering the substrate at site 2. *Phormidium* sp cyanobacteria was also present at site 2 suggesting nutrient enrichment.

Site 1 had no moss and leaves, patchy wood and no macrophyte, site 2 had patchy moss, and no leaves, wood and macrophytes, and site 3 had patchy moss, leaves and wood and no macrophytes. Sites 1 and 2 had no shade or overhanging vegetation while sites 3 had complete shading from overhanging vegetation.

Macroinvertebrate communities

Most past surveys have shown that the larger tributary supports richer macroinvertebrate communities, including abundances of 'sensitive' mayflies. These results reflect the good habitat conditions normally provided by faster-flowing, stony-bedded streams on the upper to mid reaches of the ring plain. The smaller tributary has tended to support communities with lower numbers of taxa and smaller proportions of 'sensitive' taxa. This in part has been due to the slower flow and/or iron oxide deposition on the more sedimented stream bed of this tributary.

Table 2 provides a summary of the results from previous surveys sampled in relation to the Kaimiro Production Station discharges along with current survey results.

Table 2 Number of taxa, MCI and $SQMCI_S$ values for two unnamed tributaries of the Mangaoraka Stream, sampled in relation to the Kaimiro Production Station on 1 October 2015 and a summary of historical data for these sites.

Site No.	N	No of taxa			MCI value			$SQMCI_S$ value		
		Median	Range	Oct 2015	Median	Range	Oct 2015	Median	Range	Oct 2015
1	57	27	18-37	24	97	83-110	101	3.5	1.9-5.2	5.7
2	53	15	3-26	14	81	55-103	83	2.2	1.2-4.1	2.3
3	57	24	14-33	18	99	71-111	110	4.2	1.7-6.3	4.1

Table 3 provides a summary of various macroinvertebrate indices within a specific altitudinal band for 'control' sites situated in Taranaki ring plain streams arising outside of Egmont National Park. The full results from the current survey are presented in Table 4.

Table 3 Range and median number of taxa, MCI values and SQMCIs scores for 'control' sites (Taranaki ring plain rivers/streams with sources outside Egmont National Park) at altitudes 200-249 m asl (TRC, 2015).

	No. of taxa	MCI value	$SQMCI_S$ value
No. Samples	103	103	43
Range	2-37	60-116	1.9-6.7
Median	24	95	4.0

Table 4 Macroinvertebrate fauna of two unnamed tributaries of the Mangaoraka Stream in relation to Kaimiro-A wellsite sampled on 1 October 2015.

Taxa List	Site Number	MCI score	1	2	3
	Site Code		MRK000198	MRK000204	MRK000207
	Sample Number		FWB15242	FWB15243	FWB15244
NEMATODA	Nematoda	3	-	R	-
ANNELIDA (WORMS)	Oligochaeta	1	VA	VA	VA
	Lumbricidae	5	R	-	C
MOLLUSCA	*Potamopyrgus*	4	VA	C	R
	Sphaeriidae	3	R	-	-
CRUSTACEA	Ostracoda	1	-	R	-
	Paraleptamphopidae	5	R	-	-
	Paranephrops	5	R	-	-
EPHEMEROPTERA (MAYFLIES)	*Austroclima*	7	A	-	A
	Coloburiscus	7	-	-	A
	Deleatidium	8	-	-	R
	Zephlebia group	7	XA	A	A
PLECOPTERA (STONEFLIES)	*Acroperla*	5	-	-	R
	Zelandobius	5	R	-	-
ODONATA (DRAGONFLIES)	*Antipodochlora*	5	R	-	-
HEMIPTERA (BUGS)	*Anisops*	5	R	-	-
COLEOPTERA (BEETLES)	Elmidae	6	C	-	-
	Ptilodactylidae	8	-	-	R
MEGALOPTERA (DOBSONFLIES)	*Archichauliodes*	7	-	-	C
TRICHOPTERA (CADDISFLIES)	*Hydropsyche (Aoteapsyche)*	4	-	-	R
	Ecnomidae/Psychomyiidae	6	-	R	-
	Hydrobiosis	5	R	R	R
	Hydropsyche (Orthopsyche)	9	C	-	A
	Polyplectropus	6	R	-	-
	Psilochorema	6	R	R	-
	Oxyethira	2	-	R	-
	Pycnocentria	7	R	-	R
	Triplectides	5	A	R	-
DIPTERA (TRUE FLIES)	*Aphrophila*	5	R	R	R
	Eriopterini	5	R	-	-
	Hexatomini	5	R	R	-
	Paralimnophila	6	-	C	-
	Orthocladiinae	2	R	C	-
	Polypedilum	3	-	-	R
	Austrosimulium	3	C	-	R
	Tanyderidae	4	-	-	R
ACARINA (MITES)	Acarina	5	R	-	-
		No of taxa	24	14	18
		MCI	101	83	110
		SQMCIs	5.7	2.3	4.1
		EPT (taxa)	9	5	9
		%EPT (taxa)	38	36	50
'Tolerant' taxa	'Moderately sensitive' taxa	'Highly sensitive' taxa			

R = Rare C = Common A = Abundant VA = Very Abundant XA = Extremely Abundant

Site 1

A moderate macroinvertebrate community richness of 24 taxa was found at site 1 ('control' site) at the time of the survey which was three less than the median number recorded for the site (median taxa richness 27; Table 2). Taxa richness was the same as the median calculated from similar sites (median taxa richness 24; Table 3) and lower than the previous sample (taxa richness 32; Figure 2).

The MCI score of 101 units indicated a community of 'good' biological health which was not significantly different (Stark, 1998) to the median value calculated from previous surveys at the same site (median MCI score 97; Table 2) or compared with the previous survey (taxa richness 98; Figure 2). The $SQMCI_s$ score of 5.7 units was higher (Stark, 1998) than the median value calculated from previous surveys at the same site (median $SQMCI_s$ score of 3.5 units; Table 2) but similar to the previous survey score ($SQMCI_s$ score of 5.2 units) which may indicate a prolonged improvement in this index at the site.

The community was characterised by two 'tolerant' taxa [oligochaete worms and snail (*Potamopyrgus*)] and three 'moderately sensitive' taxa [mayflies (*Austroclima* and *Zephlebia* group) and caddisfly (*Triplectides*)] (Table 4).

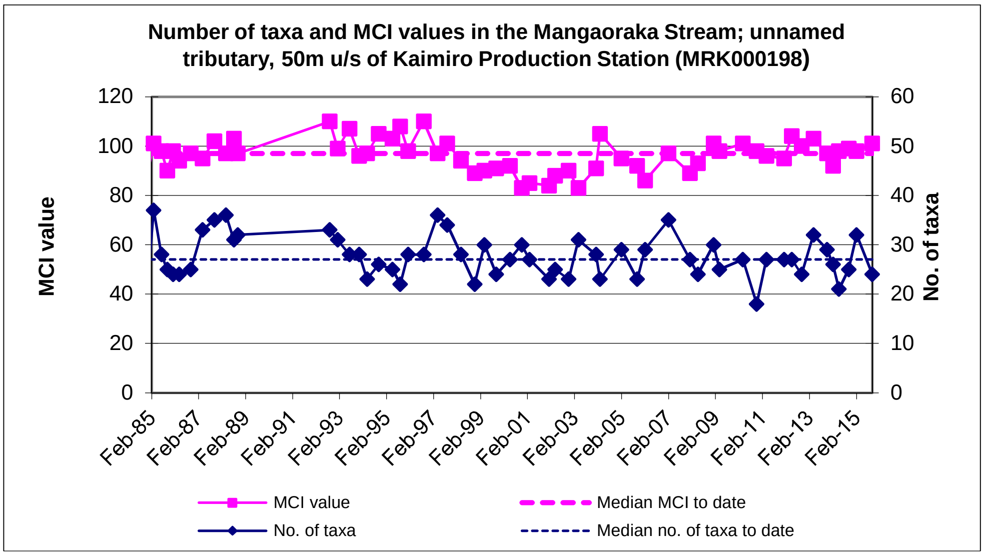

Figure 2 Number of taxa and MCI values in an unnamed tributary of the Mangaoraka Stream, 50 m upstream of Kaimiro Production Station (MRK000198)

Site 2

A moderately poor macroinvertebrate community richness of 14 taxa was found at site 2 ('primary impacted') at the time of the survey which was similar to the median number recorded for the site (median taxa richness 15; Table 2) and to the previous survey score (taxa richness 15; Figure 3). However, taxa richness was substantially lower than the median calculated from similar sites (taxa richness 24; Table 3).

The MCI score of 83 units indicated a community of 'fair' biological health which was not significantly different (Stark, 1998) to the median value calculated from previous surveys at the same site (median MCI score 81; Table 2). There was an insignificant increase (Stark, 1998) of three units from the previous survey (MCI score 80 units; Figure 3). The $SQMCI_s$ score of 2.3

units was similar to the median value calculated from previous surveys at the same site (median $SQMCI_s$ score of 2.2 units; Table 2) and lower than the previous survey score ($SQMCI_s$ score of 3.4 units).

The community was characterised by one 'tolerant' taxon (oligochaete worms) and one 'moderately sensitive' taxon [mayfly (*Zephlebia* group) (Table 4).

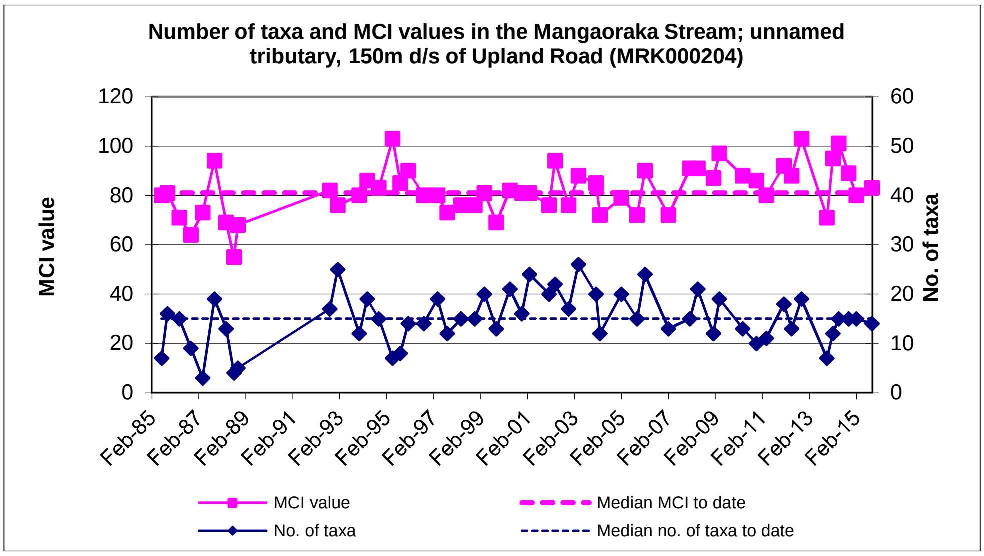

Figure 3 Number of taxa and MCI values in an unnamed tributary of the Mangaoraka Stream, 150 m d/s of Upland Road (MRK000204).

Site 3

A moderate macroinvertebrate community richness of 18 taxa was found at site 3 (secondary impacted site) at the time of the survey which was slightly lower than the median number recorded for the site (median taxa richness 24; Table 2) but similar to the previous survey score (taxa richness 16; Figure 3). Taxa richness was lower than the median calculated from similar sites (taxa richness 24; Table 3).

The MCI score of 110 units indicated a community of 'good' biological health which was significantly higher (Stark, 1998) than the median value calculated from previous surveys at the same site (median MCI score 99; Table 2). There was an insignificant increase (Stark, 1998) of seven units from the previous survey (MCI score 103 units; Figure 4). The $SQMCI_s$ score of 4.1 units was similar to the median value calculated from previous surveys at the same site (median $SQMCI_s$ score of 4.2 units; Table 2) and lower than the previous survey score ($SQMCI_s$ score of 6.3 units).

The community was characterised by one 'tolerant' taxon (oligochaete worms), three 'moderately sensitive' taxa [mayflies (*Austroclima*, *Coloburiscus* and *Zephlebia* group)], and one 'highly sensitive' taxon [caddisfly (*Hydropsyche* - *Orthopsyche*)] (Table 4).

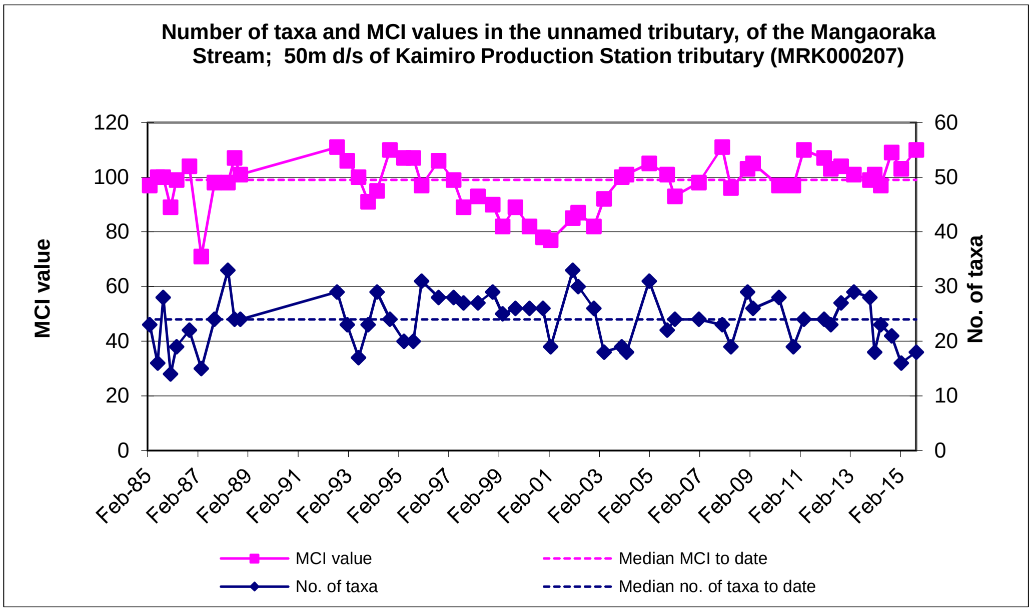

Figure 4 Number of taxa and MCI values in an unnamed tributary of the Mangaoraka Stream, 50 m d/s of the Kaimiro Production Station tributary (MRK000207).

Discussion

The Council's 'kick-sampling' technique was used at three sites to collect streambed macroinvertebrates from two unnamed tributaries of the Mangaoraka Stream in relation to the Kaimiro-A wellsite. This has provided data to assess any potential impacts of discharges from hydraulic fracturing on the macroinvertebrate communities of the stream. Samples were processed to provide number of taxa (richness), MCI, and $SQMCI_S$ scores for each site.

Taxa richness is the most robust index when ascertaining whether a macroinvertebrate community has been exposed to toxic discharges. Macroinvertebrates when exposed to toxic chemicals may die and be swept downstream or deliberately drift downstream as an avoidance mechanism (catastrophic drift). The MCI is a measure of the overall sensitivity of the macroinvertebrate community to the effects of organic pollution in stony streams. It is based on the presence/absence of taxa with varying degrees of sensitivity to environmental conditions. The $SQMCI_S$ takes into account taxa abundances as well as sensitivity to pollution. Significant differences in either the taxa richness, MCI or the $SQMCI_S$ between sites may indicate the degree of adverse effects (if any) of the discharge being monitored.

Most of the previous surveys undertaken in relation to the Kaimiro Production Station stormwater discharge have shown that the larger tributary of the Mangaoraka Stream (sites 1 and 3) supports higher taxonomic richnesses and healthier macroinvertebrate communities. The results of this spring survey were consistent with these trends with taxa richnesses, MCI and $SQMCI_S$ scores recorded at sites 1 and 3 higher than those recorded at site 2 in the minor unnamed tributary of the Mangaoraka Stream. Site 2 ('primary impacted' site) has been affected to some extent by sedimentation of the streambed from iron-oxide deposits. In this survey the site's substrate was composed of 30% silt and the hard substrate (gravels, cobbles and boulders) had a coating of iron oxide sediment which probably contributed to the lower taxa richness and abundances found at the site compared with site 1 (upstream 'control' site) and site 3 (downstream 'secondary impacted' site).

Taxonomic richness at site 1 was slightly higher than site 3 (by six taxa) at the time of the survey. Normally site 1 has slightly more taxa recorded than site 3 (site 1 median taxa richness of 27 versus site 3 median taxa richness of 24) so this result is largely congruent with past results.

There was a non-significant difference (Stark, 1998) in MCI scores between sites 1 and 3 suggesting that no organic enrichment is occurring between the upstream and downstream sites. Site 1 had a higher $SQMCI_s$ score than site 3 which was largely caused by the 'extremely abundant' *Zephlebia* group mayfly in the 'control' site sample. However, this result represented a higher than normal $SQMCI_s$ score for site 1 rather than a decline at site 3 and probably relates more to habitat variation between site 1 and 3 rather than water quality differences.

Overall, the results of this October 2015 survey suggest that hydraulic fracturing at the Kaimiro-A wellsite has not had any recent detrimental effects on the macroinvertebrate communities of the minor and main tributary of the Mangaoraka Stream. Poorer macroinvertebrate indices found at the minor tributary would be a reflection of habitat differences, most likely from naturally occurring iron oxide deposition and differences in taxa richness between sites 1 and 3 may be a reflection of habitat variation between sites.

Summary

- A macroinvertebrate survey was performed at three sites in two unnamed tributaries of the Mangaoraka Stream in relation to hydraulic fracturing at the Kaimiro-A wellsite.

- Site 2 had substantially lower macroinvertebrate indices than sites 1 and 3 which is consistent with results from past surveys and is due to the minor tributary of the Mangaoraka Stream having high iron oxide levels which causes lower habitat quality for macroinvertebrates. The major tributary of the Mangaoraka Stream which sites 1 and 3 are situated on does no have the same iron oxide issue.

- Sites 1 and 3 macroinvertebrate indices were generally consistent with previous sampling results and there were only minor differences recorded between the two sites for taxa richness and MCI scores. Site 1 continued to show a higher than usual $SQMCI_s$ score which was largely due to the mayfly *Zephlebia* group being recorded as 'extremely abundant'.

- Overall, there was no evidence that hydraulic fracturing at the Kaimiro-A wellsite had any recent detrimental effects on the macroinvertebrate communities of the minor and main tributary of the Mangaoraka Stream.

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